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ABSTRACT: *A study limited to one group of microfossils suggests only a partial resolution of stratigraphic problems, whereas an investigation of the total fossil microbiota is more effective. Tertiary sedimentary rocks lend themselves well to paleoecological studies, since many of the faunal and floral elements have modern equivalents, and they occur in assemblages similar to those of living forms. For a fuller understanding of Tertiary sediments, it is important that the ecology of Recent aquatic and terrestrial environments be appreciated. Composite studies have aided in more complete understanding of certain paleoecological problems, in closer stratigraphic correlations, and in the discerning of facies trends.*

Composite micropaleontology and its application to Tertiary and near-Recent stratigraphy

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Amherst, Massachusetts

INTRODUCTION

A paleontological study that utilizes all the organisms present to determine paleoecological conditions should be of proportionately greater value to stratigraphy than one devoted to a single group of fossil animals or plants. The Tertiary and near-Recent sediments give an excellent demonstration of how an understanding of composite biotas can aid in the solution of some stratigraphic problems. Much has been written on the taxonomy, ecology, and geography of modern microorganisms, and much of that information can be applied to investigations dealing with older organisms. The desirability of drawing from many sources of paleontological information in stratigraphy was stressed by Croneis (1942), and as a principle this is well recognized, although the practical difficulties often are a definite barrier. Few publications have described composite paleobiological studies, for most groups of micro-organisms require investigation by students with special training in each particular field. Groups of investigators working together upon a single problem could give critical depth to the analysis, but such ideal research is not practical in attacking economic problems where speed is important. It is therefore necessary in economic micropaleontology to invest in one person the responsibility of recognizing many types of organisms and understanding what each indicates. Detailed taxonomic and ecologic information cannot be thus attained, but a broadly trained micropaleontologist can obtain sufficient information for accurate stratigraphic work and a useful account of the paleoecology.

ENVIRONMENTS AND MICROFOSSILS

Marine, brackish- and fresh-water sediments contain distinctive megascopic faunas and floras that are relatively well known, but the microbiotas, though profuse and distinctive, are not nearly so well understood. This is especially true of the organisms visible only with the compound microscope and in particular of those found in brackish-water sediments. The latter probably represent the richest remaining field of micropaleontology. Brackish-water sediments contain many distinctive organisms, and this habitat is the meeting-ground of many environments. Brackish-water associations frequently have a direct bearing upon important paleogeographic and facies problems.

The foraminifera and ostracodes long have been important to stratigraphy, but a better understanding and use of the associated radiolarians, hystrichospherids, flagellates, tintinnids, sponge spicules, diatoms, spores, pollen and various plant cuticles can be a refinement of present stratigraphic paleontology. Each of these is an indicator of one or more environments, and the presence of certain forms may suggest or even prove what a single specialized group cannot prove concerning age or environment. Animal microfossils, at present, are by far the most widely used in stratigraphic studies. This is because they are better understood and their usefulness has been demonstrated. Plant microfossils until recently have been neglected by paleontologists because of their complexity and their seemingly restricted continental nature. Only in coal-seam correlation have plant micro-

fossils received much attention. Such studies have utilized the wealth of spores and pollen contained in coal.

Spores and pollen do not constitute the only microfossils of the plant kingdom. Diatoms long have been studied, and have been used for the correlation of Tertiary deposits. The charophytes have also been employed, but to a lesser extent (Peck, 1946). Cuticles and macerated wood tissues likewise occur among the plant microfossils recorded in paleobotanical literature. Studies indicate, however, that spores and pollen are the plant microfossils most important for the resolution of stratigraphic problems. The reasons for their superiority over others are that they are small, resistant, and diagnostic. Spores and pollen are reasonably identifiable as to families and genera, and frequently as to species. They are produced in great quantities, frequently in countless millions, and are distributed by wind, water, or insects. Obviously, the atmospherically distributed spores and pollen have the widest distribution, while those transported by insects may be very restricted. Such minute objects as spores and pollen may be entombed in a multitude of sediments of very local extent, whereas other plant parts usually decay without leaving recognizable fossils. A survey of sediments in which spores and pollen are preserved shows that they are most abundant in coals, shales, and siltstones.

Spores and pollen are fossils with index value because of (1) the evolution that has taken place in world floras, (2) the specific geographic distribution and migration of ancient floras, and (3) the ecologic relations of plants. Evolutionary changes in the floras of the world probably equal those which have occurred in the animal kingdom, for changes are apparent in spores and pollen from one geologic period to another. The shifting of climatic zones has, at least in part, caused great migrations and the extermination of floras or reconstitution of plant communities. These are some of the factors that make it possible to use plant fossils in stratigraphic studies.

Evolution, migration and preservation of plants and animals are governed by the same principles, and their frequent association suggests the desirability for more integrated studies. Animal microfossils are frequently quite restricted, but where the sediments are marine and extensive, they may be widespread and valuable horizon-markers. Where contemporaneous aquatic environments were restricted and differed markedly, animal fossils may be less useful for correlation. If, however, continental microfossils of known age occur in the sediments of these different environments, the problem is more easily resolved. An example of such a situation is provided by large lakes, in which both oligotrophic and eutrophic deposits are being formed. There may be little similarity between the faunas adapted to these different environments, but similar wind-borne pollen should be common to both. Usually, two groups of pollen are represented: (1) local pollen derived from the flora of the lake and its immediate periphery, and (2) regional wind-borne pollen. The former, like the animal fossils, indicates the local environment. The second represents the regional plant population and is mingled with all contemporaneous aquatic populations, thus serving as a unifying element in the paleoecological complex. Examples might also be cited from studies of near-Recent sediments in coastal areas where both brackish and marine environments occurred, and where the atmospherically borne spores and pollen are more useful for correlation than animal microfossils. Present knowledge of the taxonomy of plant microfossils is still very incomplete, and much is yet to be learned concerning the identification of both modern and fossil plants by their spores and pollen.

SAMPLING AND PREPARATION METHODS

Composite studies require special techniques of collecting, preparation, and study in order to attain satisfactory results. Collections from complete sections of rock outcrops or well cores are most desirable. If the latter are not available, well cuttings taken as frequently as practical may be used. Outcrop exposures permit detailed field study of sections, and more complete collections can be made which will aid in better understanding the subsurface equivalents. Samples from complete sections should be divided at lithologic breaks.

The preparation of micropaleontological materials varies, since the fossils differ in size and chemical composition. Fossils that require a compound microscope for examination are variously separated and concentrated, and some require thin-section preparation. Some fossils are calcareous, others are siliceous, proteinaceous or carbonaceous. This diversity frequently makes necessary the division of samples into fractions that are subjected to several preparation schedules. Samples containing radiolarians, diatoms or siliceous flagellates may be boiled in water until dispersed, and ammonium or potassium hydroxide may be used to facilitate this action. Siliceous particles present in such abundance as to mask proteinaceous and carbonaceous fossils can be dissolved by boiling in hydrofluoric acid. Calcareous material can be re-

moved by boiling in hydrochloric acid. These and other methods involve different procedures, which may vary with different samples. Details of preparation are usually described in papers devoted to the study of particular groups of fossils. In Table 1, various plant and animal microfossils are described and methods of recovery suggested.

Knowledge of Recent and near-Recent organisms is necessary for an understanding of Tertiary microfossils, and collections of reference materials should be available for comparison. Preparations of sediments from typical habitats such as marshes, fresh waters, estuaries, and various marine environments are also very useful, because much can be learned concerning the habitat of a fossil assemblage by a microscopic study of the sediments. Finally, a good library is necessary, as a micropaleontologist engaged in composite studies must have access to the literature devoted to many biologic fields.

PLEISTOCENE STUDIES

Older Pleistocene and living organisms have associations that are so similar that principles of neo-ecology can be applied. Recent plant and animal ecology furnishes a starting point for similar investigations of the earlier Pleistocene. Caution must be exercised, however, in drawing conclusions by analogy, because relationships are often very complicated. This is illustrated by a study of postglacial peat pollen from about two hundred bogs in the Middle West.

The composition of peat-pollen spectra has been influenced by various factors, among which are (1) migration routes of forest belts, (2) composition and variation of the forests with respect to geographic range, (3) climatic history since glacial time, and (4) distribution, character, and age of glacial drifts. Definite relations exist today between the composition of forests on the one hand, and climate on the other. Regardless of such a complexity of factors, there is some indication that it may be possible to identify by the fossil pollen spectrum the substage of the Wisconsin glacial drift upon which a peat deposit has developed. The best type of spectrum for this purpose is one that is constructed by totaling all the pollen recorded in a peat deposit and illustrating the result percentage-wise in a histogram.

Peat deposits resting on glacial drift older than the Tazewell have been weathered greatly and do not contain microfossils other than fresh-water sponge spicules and certain siliceous flagellates. Therefore, a pollen spectrum has not been determined for peats that occur on the earliest Wisconsin or older drifts.

Peats overlying the Tazewell and younger drifts that began to accumulate shortly after the melting of the ice possess distinctive pollen spectra in the Middle West. On Tazewell drift, *Picea* (spruce) pollen dominates, with *Quercus* (oak) a close second and *Pinus* (pine) third in abundance. Other kinds of tree pollen are present, but they are much less common. On Cary drift, *Pinus* pollen is slightly more abundant than *Picea*, and *Quercus* pollen is an important third. On the Valders and Mankato drifts, south of Lake Superior, *Pinus* pollen is usually more than twice as abundant as *Picea*, but *Quercus* pollen is rare. Immediately north of Lake Superior, on the same drifts, more than half of the pollen is referable to *Picea*, about one-fourth to *Pinus*, and *Quercus* pollen is very rare. On the Cochran moraine and northward, almost all the pollen was derived from *Picea*, with a small representation of *Pinus* and no *Quercus* pollen.

The great variation in the abundance of pollen from several tree genera in midwestern peat seems to reflect climatic zonation and progressive migration. *Picea* is dominant on the drifts north of Lake Superior because other forest elements have not yet migrated far enough north to become important in the pollen spectra. On Valders and Mankato drifts, south of Lake Superior, *Pinus* seems to have quickly reached a state of equilibrium, and *Picea* was only a transient. *Quercus* probably dominates Cary drift spectra for the same reason that *Pinus* dominates a portion of Valders and Mankato drifts. The anomaly of the series is to be found in Ohio on Tazewell drift. There, *Picea* is the most abundant pollen type in the spectrum. The Tazewell drift today supports a forest quite similar to that which characterizes the more northern Cary. The great difference in pollen spectra appears to have historical significance. Perhaps *Picea* forests persisted longer on Tazewell drift because of refrigeration during subsequent Wisconsin time.

The foregoing interpretations are somewhat tentative, and apply only to the Middle West. Comparable studies have not been completed in either the eastern or western parts of the continent. The notation of this problem illustrates the complexity of forest migration and interpretation of the microfossils in near-Recent sediments. Much of the complexity of the Pleistocene floras and faunas has been brought about by an extreme climatic fluctuation and a very complex series of glacial ice advances and retreats.

TERTIARY STUDIES

Problems of Tertiary biota are probably equally as complex as those of the Pleistocene, and evidence of

SUMMARY OF IMPORTANT MICROFOSSILS

PLANT MICROFOSSILS

TYPE	DESCRIPTION	GEOLOGIC RANGE	HABITAT	SIZE	RECOVERY
Bacteria	Cellulose Single cells, chains	Pre-Cambrian — Recent	All	ca. 1μ	Thin section
Coccolithaceae	Calcareous Imperforate and perforate plates	Cretaceous — Recent	Marine	2 — 3μ	Thin section
Silicoflagellata	Siliceous Rings, nets, etc.	Cretaceous — Recent	Marine	5 — 20μ	Dispersion KOH, HCl, HNO_3, H_2SO_4 Thin section
Dinoflagellata	Cellulose, proteinaceous Cell wall with furrows	Jurassic — Recent	Fresh, brackish, marine	10 — 20μ	Dispersion KOH, HCl, HNO_3, H_2SO_4 Thin section
Desmidaceae	Cellulose Single cell constricted in middle	Tertiary — Recent	Fresh water	0.1 — 0.5 mm.	KOH, HCl, HF
Other Chlorophyceae	Cellulose Single or colonial spheres, masses, plates, filaments	Tertiary — Recent	Fresh water	0.1 — 2 mm.	KOH, HCl, HF
Diatomaceae	Siliceous Single cell, discoidal, rhombic, elliptic, triangular	Cretaceous — Recent	Fresh, brackish, marine	5 — 60μ	HCl, HNO_3, H_2SO_4
Charophyta	Calcareous Spheres, ovoids, spiral aspect	Devonian — Recent	Fresh, brackish	1 — 3 mm.	Dispersion Thin section
Spores	Cellulose Single or groups, spheres, ovoids, etc.	Silurian — Recent	Terrigenous, fresh, brackish, marine	1 — 900μ	Dispersion KOH, HCl, HF, Schultze Solution Thin section
Pollen — Gymnospermae	Cellulose Single cells, several cells, masses	Devonian — Recent	Terrigenous, fresh, brackish, marine	10 — 130μ	Dispersion KOH, HCl, HF, Schultze Solution Thin section
Pollen — Angiospermae		Jurassic — Recent			
Trichomes	Cellulose Single to multicellular, spines, plates, etc.	Silurian — Recent	Terrigenous, fresh	20μ+	Dispersion KOH, HCl, HF Thin section
Leaf cuticles	Cellulose Cellular or noncellular	Silurian — Recent	Terrigenous, fresh, brackish, marine	10μ+	Dispersion KOH, HCl, HF, Schultze Solution Thin section
Isolated tissues or cells	Cellulose Single to multicellular fragments	Silurian — Recent	Terrigenous, fresh, brackish, marine	10μ+	Dispersion KOH, HCl, HF, Schultze Solution

ANIMAL MICROFOSSILS

TYPE	DESCRIPTION	GEOLOGIC RANGE	HABITAT	SIZE	RECOVERY
Foraminifera	Calcareous, arenaceous, chitinous Simple to complex chambers, and chamber linings	Cambrian — Recent	Marine	30μ+	Dispersion HF Thin section
Radiolaria	Siliceous Single cells, spherical or bell-shaped	Pre-Cambrian — Recent	Marine	50 — 500μ	Dispersion HCl, HNO_3, H_2SO_4 Thin section
Calpionellidae	Calcareous Unilocular, cup-shaped	Up. Jurassic — L. Cretaceous	Marine	25 × 50μ	Thin section
Porifera	Calcareous, siliceous Simple to complex spicules and fibers	Pre-Cambrian — Recent	Fresh, brackish, marine	50μ — 3 mm.	Dispersion HCl, HNO_3, H_2SO_4 Thin section
Alcyonarian spicules	Calcareous, horny? Acicular, granular, glossy	Up. Cretaceous — Tertiary	Marine	1 — 3 mm.	Dispersion Thin section
Echinodermata	Calcareous Plates, discs, columnals, spines, etc.	Ordovician — Recent	Marine	0.5 mm.	Dispersion Thin section
Ostracoda	Calcareous, chitinous Carapaces, appendages	Ordovician — Recent	Fresh, brackish, marine	0.5 — 5 mm.	Dispersion Thin section
Other Arthropoda	Chitinous Skeletal fragments	Cambrian — Recent	Fresh, brackish, marine	50μ+	Dispersion HCl, HF Thin section
Scolecodonts	Chitinous Jaws, cusps	Cambrian — Recent	Brackish, marine	50μ — 5 mm.	Dispersion HCl Thin section
Conodonts	Phosphatic Plates, cuspate jaws	Cambrian — Triassic	Marine	100μ — 3 mm.	Dispersion HCl Thin section

MICROFOSSILS OF UNCERTAIN AFFINITY

TYPE	DESCRIPTION	GEOLOGIC RANGE	HABITAT	SIZE	RECOVERY
Discoasteridae	Calcareous Discs, asters	Up. Cretaceous — Tertiary	Marine	20 — 35μ	Dispersion HF
Hystrichosphaerida	Proteinaceous Spheres, ovoids, spiny, smooth	Pre-Cambrian — Recent	Brackish, marine	10 — 400μ	Thin section HCl, HF
Chitinozoa	Proteinaceous? Tubes, flasks, urn-shaped	Cambrian — Mississippian	Marine	50μ — 1 mm.	Thin section HCl, HF
Nannoconus	Calcareous Cone-like, central canal, wedge-shaped elements	Jurassic — Cretaceous	Marine	100 — 180μ	Thin section
Oligostegina	Calcareous Spheres	Cretaceous	Marine	50μ+	Thin section
Fragmenta	Calcareous, carbonaceous Spheres, masses, spines, etc.	Pre-Cambrian — Recent	Fresh, brackish, marine	10μ+	Thin section HCl, HF

Tertiary floral and faunal migrations is well known. Current studies of North American Tertiary spores and pollen have not progressed sufficiently to make secure conclusions possible, but they seem to substantiate evidence furnished by the megafossils.

The spores and pollen of the Fort Union (Paleocene) coals suggest assemblages similar to those described as the Arcto-Tertiary flora by Chaney (1947) and others. An illustration of how plant microfossils substantiate the findings of paleobotanists is furnished by the discovery of *Metasequoia* in China and the reanalysis (Chaney, 1948) of the Arcto-Tertiary flora in North America. Previously, the flora of the Fort Union formation seemed unexplainably peculiar because of the association of pollen of *Sequoia* (now recognized as *Metasequoia*), cycads, oak, cypress, hickory and several other apparently incompatible forest types. Since *Metasequoia* was discovered and its ecology observed, the Fort Union assemblage no longer appears anomolous, because essentially this same assemblage exists today in China and is also recognized in fossil leaf assemblages in North America.

Green River (Eocene) plant microfossils concur with other kinds of geologic evidence in establishing the existence of deserts, mountains, and warm temperate environments near the Green River lakes. Wodehouse (1933) demonstrated the close correlation between the pollen and the megafossils.

The Tertiary deposits of Florida and other parts of the Gulf Coast illustrate the stratigraphic usefulness of composite studies. There, fluctuating sea level resulted in the deposition of alternating continental and marine sediments. At times, the coastal region was swampy and populated with warm temperate or subtropical vegetation. Abundant micro-organisms existed in the extensive fresh-water lagoons and estuaries or brackish-water habitats that fringed much of the coastline. Seaward, the marine waters supported a variety of faunas. Wind-borne pollen from the continent was contributed to all of these environments.

Fluctuating sea level resulted in the shifting of environments that can now be recognized by their characteristic floras and faunas. Many of the organisms are relatively unknown because of their microscopic size, but there is evidence that some of them are excellent horizon markers and indicators of paleoecological conditions. Among those important in composite microfossil studies are the "microforaminifera" described by Wilson and Hoffmeister (1952). These fossils probably represent megalospheric remains since most can be identified with the microspheric forms. Many of their tests are of calcium carbonate, which, when treated with hydrofluoric acid used to process other fossils, is converted to calcium fluoride, but the tests retain their original morphologic appearance. If the tests are subjected to hydrochloric acid, the calcium carbonate is dissolved, leaving test linings which may easily be misidentified as marine fungi. The use of megalospheric foraminifera in paleoecology and stratigraphy is a field worth further investigation. Another important group of little-known animals is the Hystrichosphaeridae. They are indicators of brackish and marine waters, and frequently occur when no other organisms are present. The siliceous lorica-forming flagellates *Trachelomonas* and *Carnegia* are essentially fresh-water organisms, but are frequently found associated with marine sediments at the mouths of rivers, and such association is excellent evidence of continental proximity. Isolated spores, pollen and plant cuticles need more study especially as to their identification with the parent plants. When this is known, they will be excellent ecological indicators and horizon-markers.

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ABSTRACT: *The Oligocene of the Carmen-Zambrano area is divided into five foraminiferal zones and two subzones, the Lower Miocene into two zones; the Middle Miocene contains one zonule. A gradual filling-in of the basin is suggested, which was interrupted in the Carmen area by deepening of the sea during the upper Lower Oligocene and the Middle Oligocene, and at the end of the Upper Oligocene. The zones are correlated with faunal units from other parts of the Caribbean area. Ten new species and one new variety are described.*

Oligocene and Lower Miocene biostratigraphy of the Carmen-Zambraon area, Colombia

V. PETTERS AND R. SARMIENTO S.

International Petroleum (Colombia) Ltd., Bogotá, and
Carter Oil Company, Tulsa, Oklahoma

INTRODUCTION

Rather extensive papers by Cushman and Renz (1941), Cushman and Stainforth (1945), Stainforth (1948*b*), Hedberg (1937), Renz (1948), and others deal with the Tertiary foraminifera and biostratigraphy of the Caribbean area east of Colombia. Cushman and Stainforth (1951), Cushman and Stevenson (1948), Cushman and Stone (1947, 1949*a*, 1949*b*), and Stainforth (1948*a*) have written on the same subjects with regard to the west coast of South America south of Colombia. Very little is known, however, of the microfaunas of the Tertiary basins of Colombia itself, although they form a link between the Caribbean and Pacific areas. A better knowledge of them should throw considerable light on the development of the present divide between the Atlantic and Pacific Oceans in this northwestern corner of South America. Papers by H. Buergl and others (1955), Redmond (1953), and Tolmachoff (1934), and a few notes in the publications of F. M. Anderson (1928), Renz (1948), Royo y Gomez (1942, 1950), and Stainforth (1948*a*), represent about all we know about the Tertiary foraminifera of Colombia.

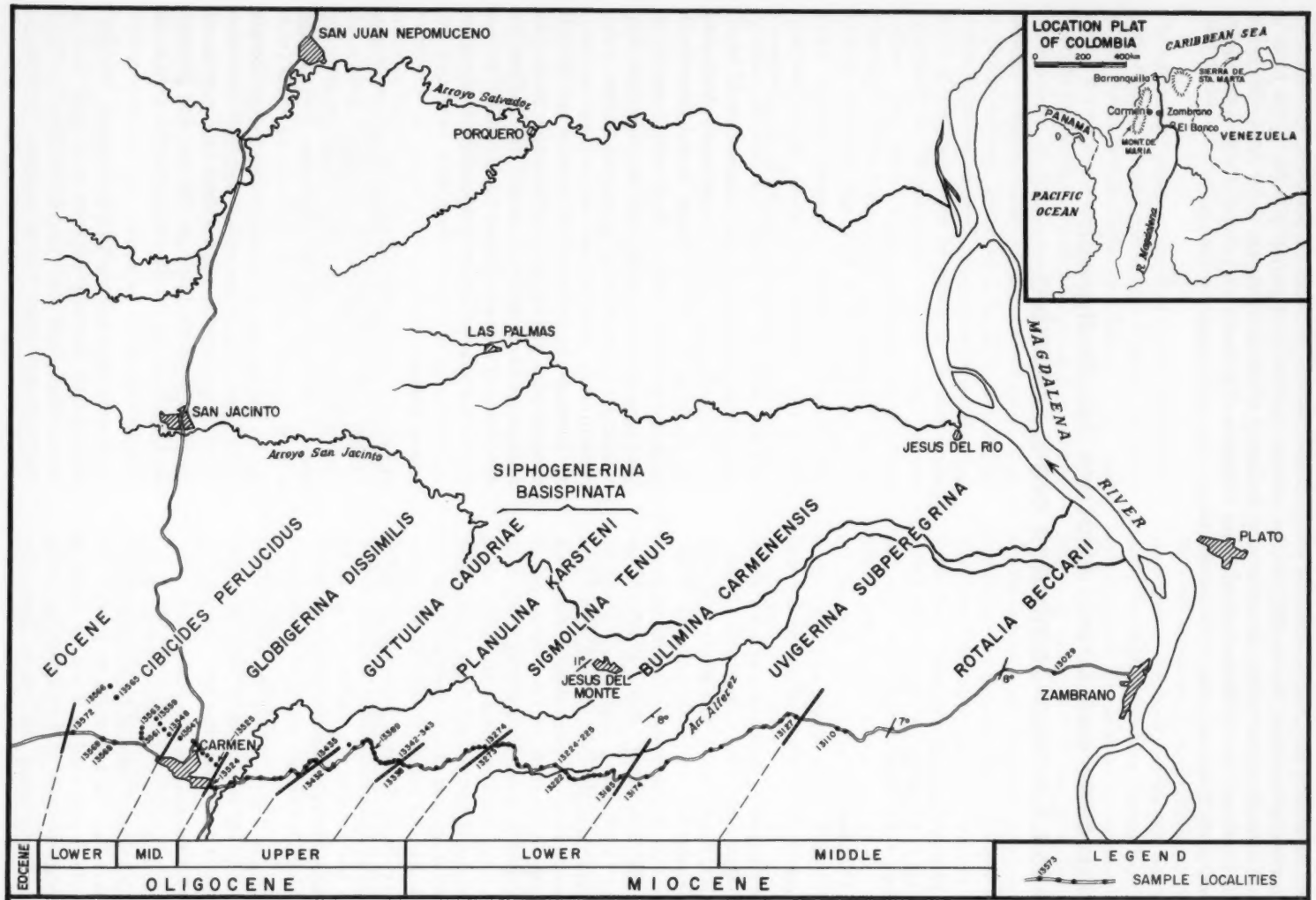
The primary scope of this paper is biostratigraphic. The description of new forms has been limited to a necessary minimum.

The authors wish to thank the Management of the International Petroleum Company, both in Bogotá and in Coral Gables, Fla., for permission to publish this paper. The findings expressed in it are the result of studies by various members of the Exploration Group of the Tropical Oil Company and Intercol during the past ten years. W. E. Denton collected the material and contributed the geological information; C. M. B. Caudri charted about half the material and supplied the names of the Eocene larger foraminifera; C. D. Redmond outlined most of the zonation; and F. V. Stevenson made the megafossil determinations. The authors are responsible for the general revision of this previous work, which has been accumulated in numerous Company reports; for facies analysis and correlation with other parts of the Caribbean area; for specific determinations of smaller foraminifera; and for the description of the new species. Lastly, thanks are due to Miss Soffy Torres G., who prepared the illustrations.

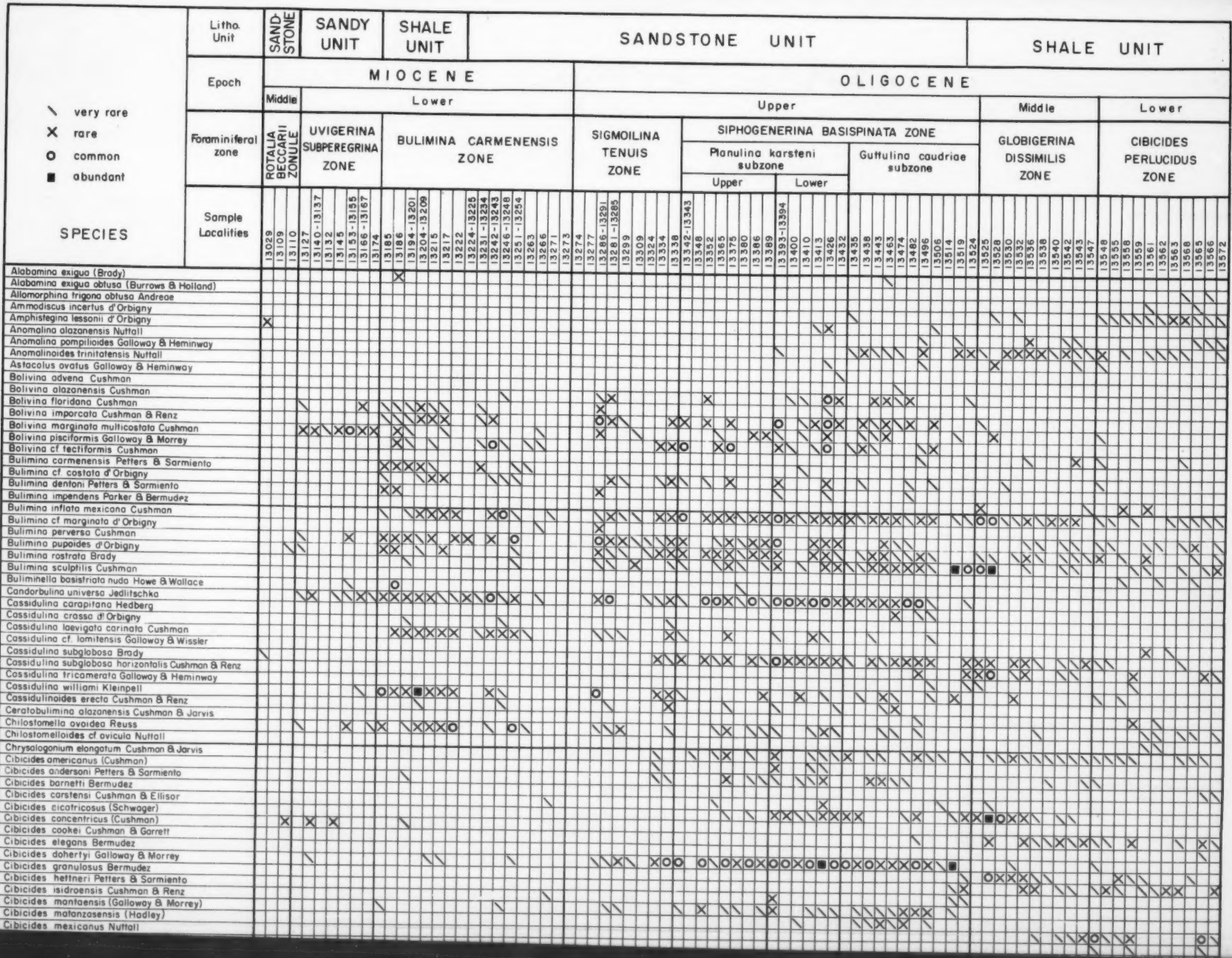
GENERAL REMARKS

The faunas described in this paper come from an area 135 km. south of Barranquilla (see insert, text-fig. 1). They were collected along the road leading from the town of Zambrano on the Magdalena River to the town of Carmen east of the Montañas de Maria (text-fig. 1). The section is situated on the western margin of the Lower Magdalena basin, which extends between the aforementioned mountain range on the west and the Sierra de Santa Marta on the east, and between the Caribbean Sea on the north and the town of El Banco on the south.

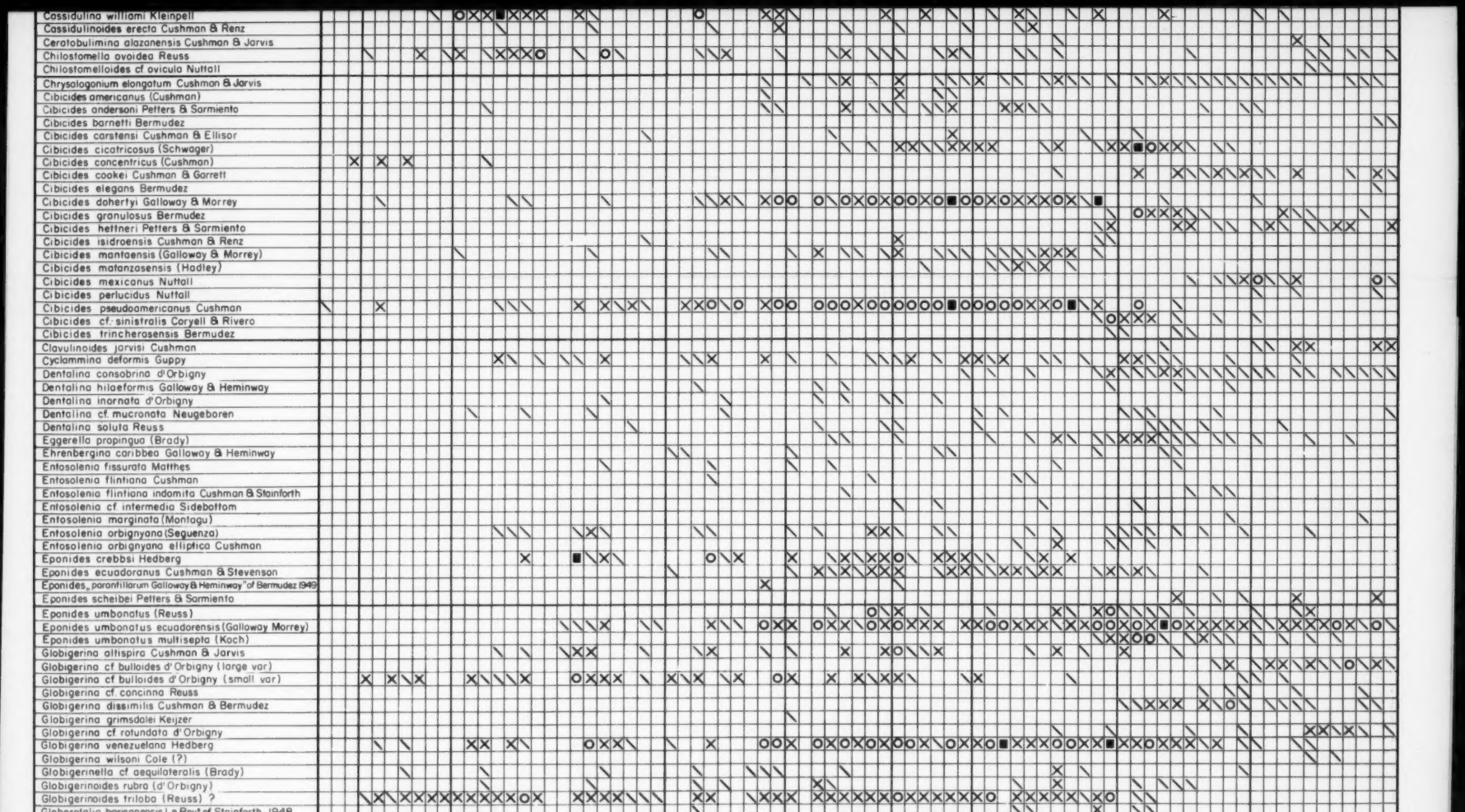
No formational names are used in this paper. The published names that may apply to these beds, such as Bombo shales and San Antonio sandstone of Beck (1921), Pacini shales, Cerrito formation, and Savana

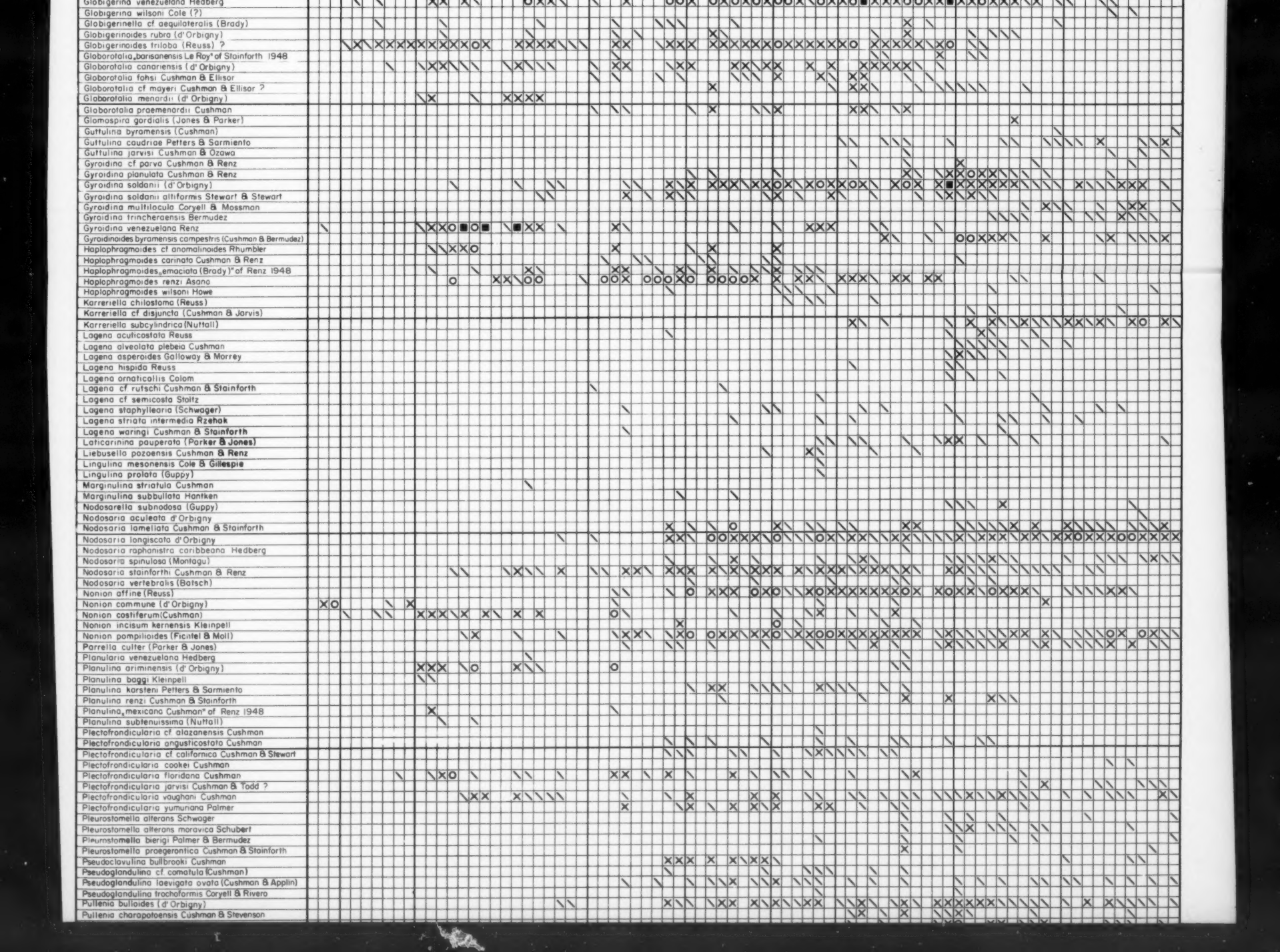


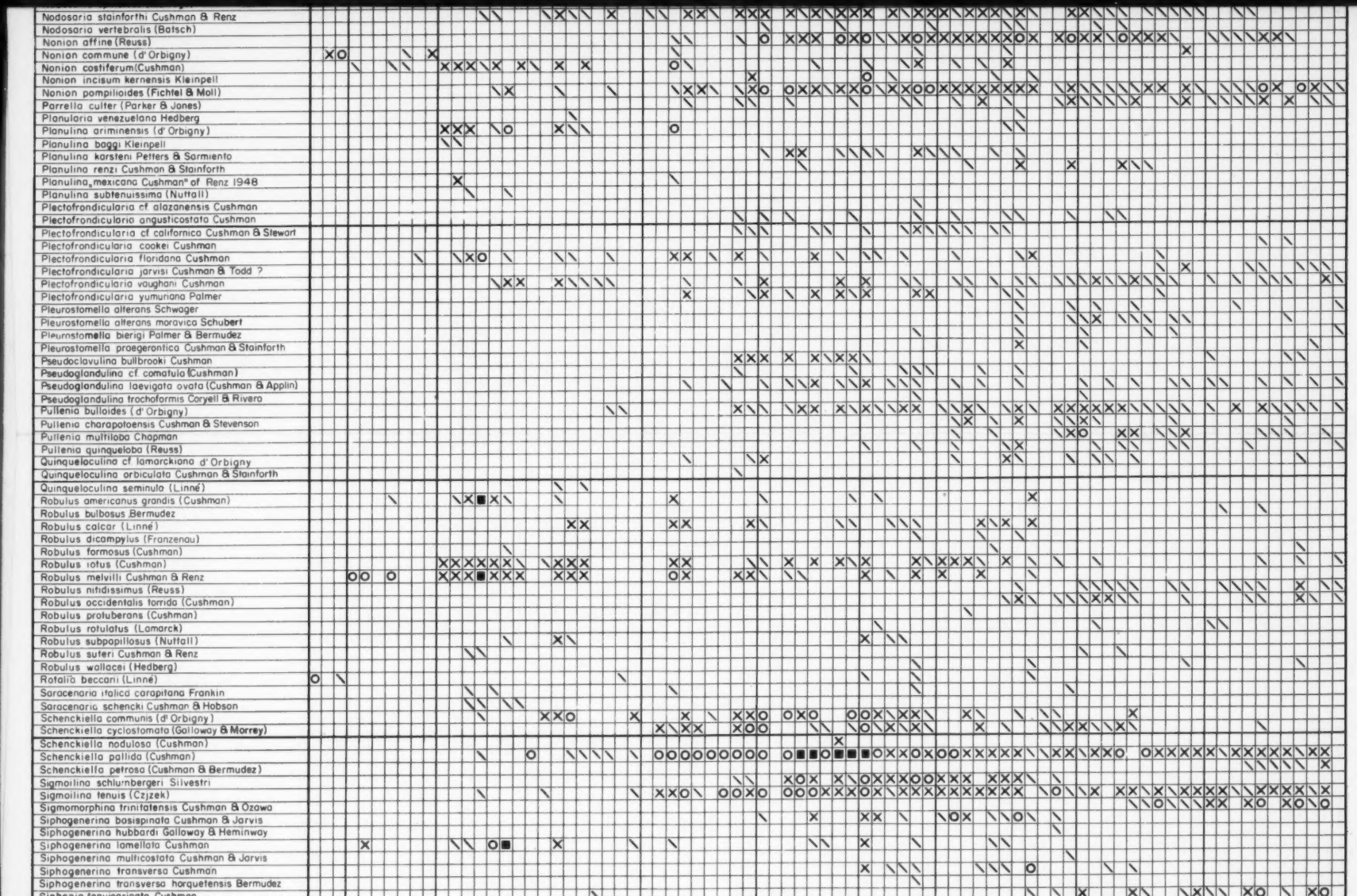
TEXT-FIGURE 1



TEXT-FIGURE 1


Cassidulina williami Kleinpell
Cassidulinoides erecta Cushman & Renz
Cerotobulimina alazanensis Cushman & Jarvis
Chilostomella ovoidea Reuss
Chilostomelloides cf. oviculo Nuttall
Chrysalogonium elongatum Cushman & Jarvis
Cibicides americanus (Cushman)
Cibicides andersoni Petters & Sarmiento
Cibicides barnetti Bermudez
Cibicides carstensi Cushman & Ellisor
Cibicides cicatricosus (Schwager)
Cibicides concentricus (Cushman)
Cibicides cookei Cushman & Garrett
Cibicides elegans Bermudez
Cibicides dohertyi Galloway & Morrey
Cibicides granulosus Bermudez
Cibicides hettneri Petters & Sarmiento
Cibicides isidroensis Cushman & Renz
Cibicides mantaensis (Galloway & Morrey)
Cibicides matanzasensis (Hadley)
Cibicides mexicanus Nuttall
Cibicides perlucidus Nuttall
Cibicides pseudoamericanus Cushman
Cibicides cf. sinistralis Coryell & Rivero
Cibicides trincherasensis Bermudez
Clavulinoides jarvisi Cushman
Cyclammina deformis Guppy
Dentalina consobrina d'Orbigny
Dentalina hilaeformis Galloway & Heminway
Dentalina inornata d'Orbigny
Dentalina cf. mucronata Neugeboren
Dentalina soluta Reuss
Eggerella propingua (Brady)
Ehrenbergina caribbea Galloway & Heminway
Entosolenia fissurata Matthes
Entosolenia flintiana Cushman
Entosolenia flintiana indomita Cushman & Stainforth
Entosolenia cf. intermedia Sidebottom
Entosolenia marginata (Montagu)
Entosolenia orbignyana (Seguenza)
Entosolenia orbignyana elliptica Cushman
Eponides crebbsi Hedberg
Eponides ecuadoranus Cushman & Stevenson
Eponides „paranfillarum Galloway & Heminway" of Bermudez 1949
Eponides scheibei Petters & Sarmiento
Eponides umbonatus (Reuss)
Eponides umbonatus ecuadorensis (Galloway Morrey)
Eponides umbonatus multisepta (Koch)
Globigerina altispira Cushman & Jarvis
Globigerina cf. bulloides d'Orbigny (large var)
Globigerina cf. bulloides d'Orbigny (small var)
Globigerina cf. concinna Reuss
Globigerina dissimilis Cushman & Bermudez
Globigerina grimsdalei Keijzer
Globigerina cf. rotundata d'Orbigny
Globigerina venezuelana Hedberg
Globigerina wilsoni Cole (?)
Globigerinella cf. aequilateralis (Brady)
Globigerinoides rubra (d'Orbigny)
Globigerinoides triloba (Reuss) ?


Globigerina venezuelana Hedberg
Globigerina wilsoni Cole (?)
Globigerinella cf aequilateralis (Brady)
Globigerinoides rubra (d'Orbigny)
Globigerinoides triloba (Reuss) ?
Globorotalia „barisanensis Le Roy" of Stainforth 1948
Globorotalia canariensis (d'Orbigny)
Globorotalia fohsi Cushman & Ellisor
Globorotalia cf mayeri Cushman & Ellisor ?
Globorotalia menardii (d'Orbigny)
Globorotalia praemenardii Cushman
Glomospira gordialis (Jones & Parker)
Guttulina byramensis (Cushman)
Guttulina caudriae Petters & Sarmiento
Guttulina jarvisi Cushman & Ozawa
Gyroidina cf parva Cushman & Renz
Gyroidina planulata Cushman & Renz
Gyroidina soldanii (d'Orbigny)
Gyroidina soldanii altiformis Stewart & Stewart
Gyroidina multiloculo Coryell & Mossman
Gyroidina trinchereaensis Bermudez
Gyroidina venezuelana Renz
Gyroidinoides byramensis compestris (Cushman & Bermudez)
Haplophragmoides cf anomalinoides Rhumbler
Haplophragmoides carinata Cushman & Renz
Haplophragmoides „emaciata (Brady)" of Renz 1948
Haplophragmoides renzi Asano
Haplophragmoides wilsoni Howe
Karreriella chilostoma (Reuss)
Karreriella cf disjuncta (Cushman & Jarvis)
Karreriella subcylindrica (Nuttall)
Lagena acuticostata Reuss
Lagena alveolata plebeia Cushman
Lagena asperoides Galloway & Morrey
Lagena hispida Reuss
Lagena ornaticollis Colom
Lagena cf rutschi Cushman & Stainforth
Lagena cf semicosta Stoltz
Lagena staphyllearia (Schwager)
Lagena striata intermedia Rzehak
Lagena waringi Cushman & Stainforth
Laticarinina pauperata (Parker & Jones)
Liebusella pozoensis Cushman & Renz
Lingulina mesonensis Cole & Gillespie
Lingulina prolata (Guppy)
Marginulina striatula Cushman
Marginulina subbullata Hantken
Nodosarella subnodosa (Guppy)
Nodosaria aculeata d'Orbigny
Nodosaria lamellata Cushman & Stainforth
Nodosaria longiscata d'Orbigny
Nodosaria raphanistra caribbeana Hedberg
Nodosaria spinulosa (Montagu)
Nodosaria stainforthi Cushman & Renz
Nodosaria vertebralis (Batsch)
Nonion affine (Reuss)
Nonion commune (d'Orbigny)
Nonion costiferum (Cushman)
Nonion incisum kernensis Kleinpell
Nonion pompilioides (Ficatel & Moll)
Parrella culter (Parker & Jones)
Planularia venezuelana Hedberg
Planulina ariminensis (d'Orbigny)
Planulina baggi Kleinpell
Planulina karsteni Petters & Sarmiento
Planulina renzi Cushman & Stainforth
Planulina „mexicana Cushman" of Renz 1948
Planulina subtenuissima (Nuttall)
Plectofrondicularia cf alazanensis Cushman
Plectofrondicularia angusticostata Cushman
Plectofrondicularia cf californica Cushman & Stewart
Plectofrondicularia cookei Cushman
Plectofrondicularia floridana Cushman
Plectofrondicularia jarvisi Cushman & Todd ?
Plectofrondicularia vaughani Cushman
Plectofrondicularia yumunana Palmer
Pleurostomella alterans Schwager
Pleurostomella alterans moravica Schubert
Pleurostomella bierigi Palmer & Bermudez
Pleurostomella praegerontica Cushman & Stainforth
Pseudoclavulina bullbrooki Cushman
Pseudoglandulina cf. comatula (Cushman)
Pseudoglandulina laevigata ovata (Cushman & Applin)
Pseudoglandulina trochoformis Coryell & Rivero
Pullenia bulloides (d'Orbigny)
Pullenia charapotoensis Cushman & Stevenson


Nodosaria stainforthi Cushman & Renz
Nodosaria vertebralis (Batsch)
Nonion affine (Reuss)
Nonion commune (d' Orbigny)
Nonion costiferum (Cushman)
Nonion incisum kernensis Kleinpell
Nonion pompilioides (Fichtel & Moll)
Parrella culter (Parker & Jones)
Planularia venezuelana Hedberg
Planulina ariminensis (d' Orbigny)
Planulina baggi Kleinpell
Planulina karsteni Petters & Sarmiento
Planulina renzi Cushman & Stainforth
Planulina mexicana Cushman" of Renz 1948
Planulina subtenuissima (Nuttall)
Plectofrondicularia cf. alazanensis Cushman
Plectofrondicularia angusticostata Cushman
Plectofrondicularia cf. californica Cushman & Stewart
Plectofrondicularia cookei Cushman
Plectofrondicularia floridana Cushman
Plectofrondicularia jarvisi Cushman & Todd ?
Plectofrondicularia vaughani Cushman
Plectofrondicularia yumuriana Palmer
Pleurostomella alterans Schwager
Pleurostomella alterans moravica Schubert
Pleurostomella bierigi Palmer & Bermudez
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Pseudoclavulina bullbrooki Cushman
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Pseudoglandulina laevigata ovata (Cushman & Applin)
Pseudoglandulina trochoformis Coryell & Rivero
Pullenia bulloides (d' Orbigny)
Pullenia charapotoensis Cushman & Stevenson
Pullenia multiloba Chapman
Pullenia quinqueloba (Reuss)
Quinqueloculina cf. lamarckiana d' Orbigny
Quinqueloculina orbiculata Cushman & Stainforth
Quinqueloculina seminula (Linné)
Robulus americanus grandis (Cushman)
Robulus bulbosus Bermudez
Robulus calcar (Linné)
Robulus dicampylus (Franzenau)
Robulus formosus (Cushman)
Robulus iotus (Cushman)
Robulus melvilli Cushman & Renz
Robulus nitidissimus (Reuss)
Robulus occidentalis torrida (Cushman)
Robulus protuberans (Cushman)
Robulus rotulatus (Lamarck)
Robulus subpapillosus (Nuttall)
Robulus suteri Cushman & Renz
Robulus wallacei (Hedberg)
Rotalia beccarii (Linné)
Saracenaria italica carapitana Frankin
Saracenaria schencki Cushman & Hobson
Schenckiella communis (d' Orbigny)
Schenckiella cyclostomata (Galloway & Morrey)
Schenckiella nodulosa (Cushman)
Schenckiella pallida (Cushman)
Schenckiella petrosa (Cushman & Bermudez)
Sigmoilina schlumbergeri Silvestri
Sigmoilina tenuis (Czjzek)
Sigmomorphina trinitatensis Cushman & Ozawa
Siphogenerina basispinata Cushman & Jarvis
Siphogenerina hubbardi Galloway & Heminway
Siphogenerina lamellata Cushman
Siphogenerina multicostata Cushman & Jarvis
Siphogenerina transversa Cushman
Siphogenerina transversa harquetensis Bermudez

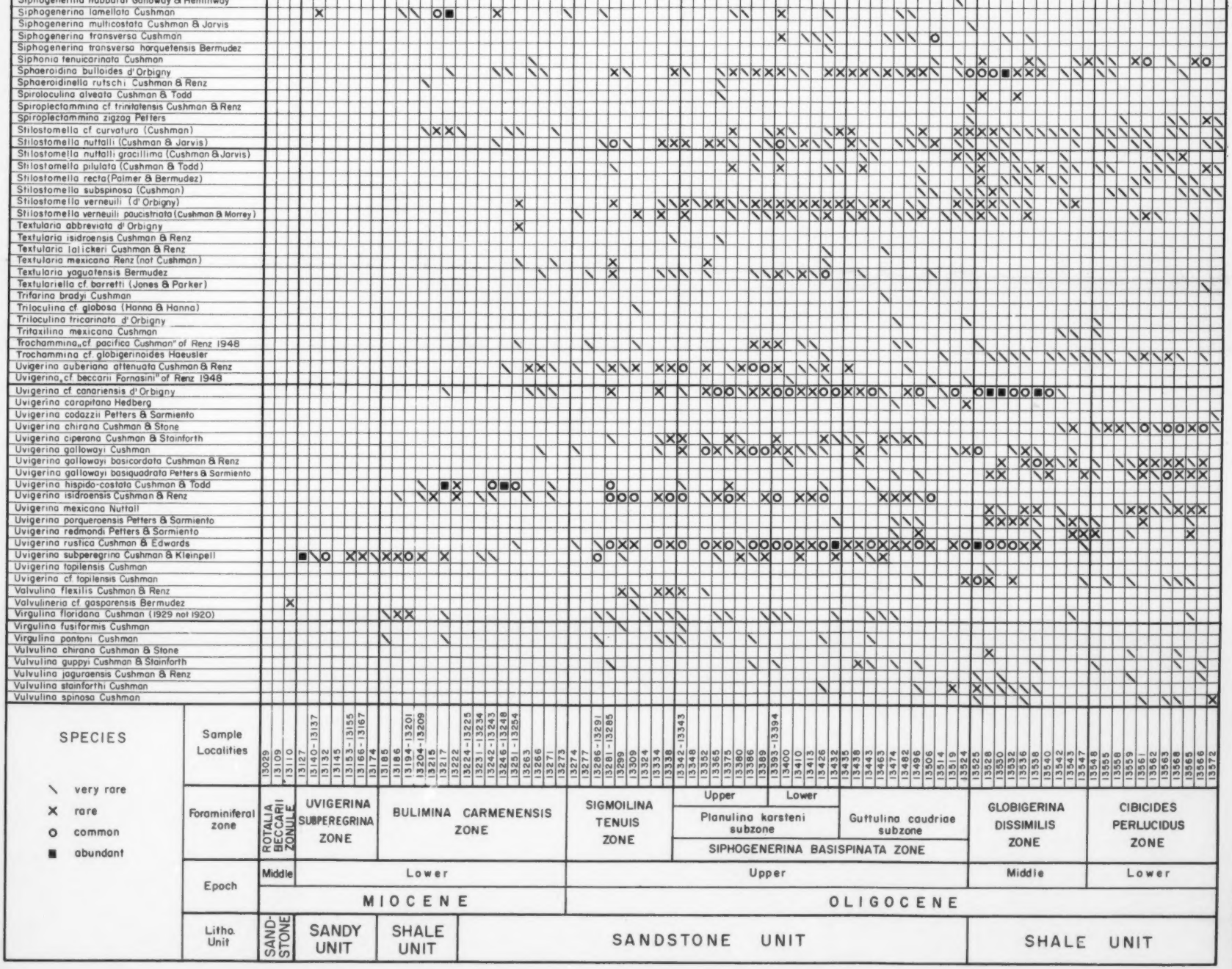
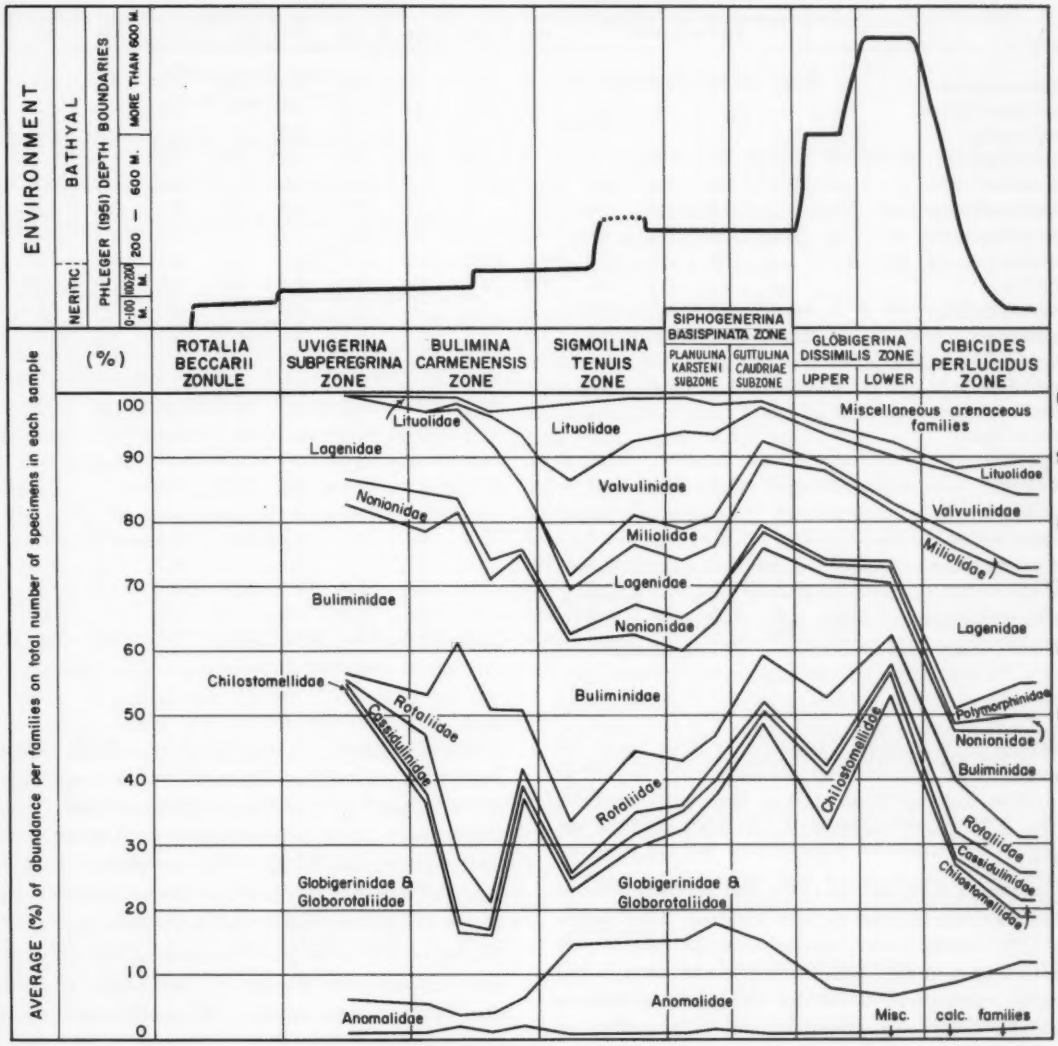

Siphogenerina lamellata Cushman
Siphogenerina multicostata Cushman & Jarvis
Siphogenerina transversa Cushman
Siphogenerina transversa horquetensis Bermudez
Siphonia tenuicarinata Cushman
Sphaeroidina bulloides d'Orbigny
Sphaeroidinella rutschi Cushman & Renz
Spiroloculina alveata Cushman & Todd
Spiroplectammina cf trinitatensis Cushman & Renz
Spiroplectammina zigzag Petters
Stilostomella cf curvatura (Cushman)
Stilostomella nuttalli (Cushman & Jarvis)
Stilostomella nuttalli gracillima (Cushman & Jarvis)
Stilostomella pilulata (Cushman & Todd)
Stilostomella recta (Palmer & Bermudez)
Stilostomella subspinosa (Cushman)
Stilostomella verneuili (d'Orbigny)
Stilostomella verneuili paucistriata (Cushman & Morrey)
Textularia abbreviata d'Orbigny
Textularia isidroensis Cushman & Renz
Textularia lalickeri Cushman & Renz
Textularia mexicana Renz (not Cushman)
Textularia yaguatensis Bermudez
Textulariella cf barretti (Jones & Parker)
Trifarina bradyi Cushman
Triloculina cf globosa (Hanna & Hanna)
Triloculina tricarinata d'Orbigny
Tritaxilina mexicana Cushman
Trochammina„cf pacifica Cushman" of Renz 1948
Trochammina cf globigerinoides Haeusler
Uvigerina auberiana attenuata Cushman & Renz
Uvigerina„cf beccarii Fornasini" of Renz 1948
Uvigerina cf canariensis d'Orbigny
Uvigerina carapitana Hedberg
Uvigerina codazzii Petters & Sarmiento
Uvigerina chirana Cushman & Stone
Uvigerina ciperana Cushman & Stainforth
Uvigerina galloway Cushman
Uvigerina galloway basicordata Cushman & Renz
Uvigerina galloway basiquadrata Petters & Sarmiento
Uvigerina hispido-costata Cushman & Todd
Uvigerina isidroensis Cushman & Renz
Uvigerina mexicana Nuttall
Uvigerina porgueroensis Petters & Sarmiento
Uvigerina redmondi Petters & Sarmiento
Uvigerina rustica Cushman & Edwards
Uvigerina subperegrina Cushman & Kleinpell
Uvigerina topilensis Cushman
Uvigerina cf topilensis Cushman
Valvulina flexilis Cushman & Renz
Valvulineria cf gasparensis Bermudez
Virgulina floridana Cushman (1929 not 1920)
Virgulina fusiformis Cushman
Virgulina pontoni Cushman
Vulvulina chirana Cushman & Stone
Vulvulina guppyi Cushman & Stainforth
Vulvulina jaguaraensis Cushman & Renz
Vulvulina stainforthi Cushman
Vulvulina spinosa Cushman
SPECIES
very rare
rare
common
abundant
Sample Localities
13029 13109 13110 13127 13140-13137 13132 13145 13153-13155 13166-13167 13174 13185 13186 13194-13201 13204-13209 13215 13217 13222 13224-13225 13231-13234 13242-13243 13246-13248 13251-13254 13263 13266 13271 13273 13274 13277 13286-13291 13281-13285 13299 13309 13324 13334 13338 13342-13343 13348 13352 13365 13375 13380 13386 13389 13393-13394 13400 13410 13413 13426 13432 13435 13438 13443 13463 13474 13482 13496 13506 13514 13519 13524 13525 13528 13530 13532 13536 13538 13540 13542 13543 13547 13548 13555 13558 13559 13561 13562 13563 13568 13565 13566 13572
Foraminiferal zone
ROTALIA BECCARII ZONULE
UVIGERINA SUBPEREGRINA ZONE
BULIMINA CARMENENSIS ZONE
SIGMOILINA TENUIS ZONE
Upper
Lower
Planulina karsteni subzone
Guttulina caudriae subzone
SIPHOGENERINA BASISPINATA ZONE
GLOBIGERINA DISSIMILIS ZONE
CIBICIDES PERLUCIDUS ZONE
Epoch
Middle
Lower
Upper
Middle
Lower
MIOCENE
OLIGOCENE
Litho. Unit
SAND-STONE
SANDY UNIT
SHALE UNIT
SANDSTONE UNIT
SHALE UNIT

TABLE 1

RANGE OF THE FORAMINIFERA IN THE CARMEN-ZAMBRANO SECTION

CARMEN - ZAMBRANO SECTION

DISTRIBUTION OF FORAMINIFERAL FAMILIES
AND
ENVIRONMENT CONDITIONS



ENVIRONMENTS:

——— Normal marine

····· Marine, but with low oxygen content - stagnant (?)

– – – – Brackish

TEXT-FIGURE 2

TABLE 2

AVERAGE PERCENTAGES OF FORAMINIFERAL FAMILIES PRESENT BY ZONES IN THE CARMEN-ZAMBRANO SECTION

FAMILIES	*Uvigerina subperegrina* zone	*Bulimina carmenensis* zone				*Sigmoilina tenuis* zone			*Siphogenerina basispinata* zone			*Globigerina dissimilis* zone		*Cibicides perlucidus* zone	
		various levels				up.	mid.	low.	*Planulina karsteni* subzone up.	*Planulina karsteni* subzone low.	*Guttulina caudriae* subzone	up.	low.	up.	low.
Rhizamminidae	—	—	—	2.4	—	—	3.2	—	0.1	0.1	0.1	3.1	1.3	2.5	2.5
Hyperamminidae	—	—	—	—	—	—	—	—	—	—	—	0.1	2.3	5.4	1.2
Reophacidae	0.3	0.4	—	—	1.7	—	—	—	0.1	0.3	0.1	0.1	0.5	0.9	1.1
Ammodiscidae	—	—	—	0.5	—	—	0.8	0.2	0.1	0.2	0.2	0.5	1.1	1.4	1.3
Lituolidae	—	2.4	1.3	0.4	3.7	11.3	26.9	7.0	5.5	4.9	0.7	1.1	1.9	0.5	5.1
Textulariidae	—	—	0.2	0.2	0.5	0.7	—	—	0.1	0.7	0.9	1.2	0.9	1.0	2.6
Verneuilinidae	—	—	—	—	—	—	—	—	0.2	—	—	—	0.1	—	—
Valvulinidae	—	—	0.6	0.4	7.9	14.4	42.5	11.6	14.0	12.5	5.2	4.1	6.9	9.0	11.1
Miliolidae	—	—	—	0.1	—	1.9	6.4	4.4	5.5	4.1	2.9	0.9	1.3	2.7	1.3
Trochamminidae	—	0.2	0.1	0.1	0.4	1.4	—	—	0.4	0.9	0.2	0.5	1.6	0.8	1.8
Lagenidae	13.3	13.0	14.2	18.0	10.3	7.0	1.8	9.7	9.1	8.6	10.3	15.1	8.9	25.2	17.1
Polymorphinidae	—	—	—	—	—	—	—	—	—	—	0.4	0.1	1.3	2.5	5.1
Nonionidae	3.7	5.4	1.9	2.8	0.4	0.8	0.1	4.0	4.9	3.2	3.2	1.5	1.8	1.0	2.3
Heterohelicidae	0.3	0.4	2.3	1.4	2.4	0.6	0.1	1.4	0.9	0.7	0.5	0.6	0.4	0.5	1.4
Buliminidae	26.6	26.3	19.9	20.3	24.3	28.4	8.2	18.5	16.6	18.0	16.2	18.3	7.5	7.3	16.4
Ellipsoidinidae	—	—	—	—	—	—	—	—	0.1	0.1	0.1	—	0.8	—	0.3
Rotaliidae	0.7	6.0	33.0	30.0	8.7	8.4	0.8	9.3	6.3	5.2	7.0	11.4	5.1	7.9	5.4
Amphisteginidae	0.2	0.1	0.4	0.4	0.3	0.3	—	—	—	0.4	—	—	—	—	—
Cassidulinidae	0.3	8.4	10.5	3.9	2.5	1.0	2.8	4.5	2.1	1.6	2.2	1.3	1.0	4.3	4.2
Chilostomellidae	1.7	1.0	1.2	0.4	0.4	0.6	0.4	1.2	2.2	1.8	1.4	8.3	2.5	0.4	2.5
Globigerinidae	47.0	29.1	13.2	9.9	32.0	8.6	2.9	15.0	17.3	19.5	32.0	24.4	47.7	18.9	6.9
Globorotaliidae	0.3	2.6	0.2	2.5	0.4	0.3	0.1	0.3	0.5	0.9	1.8	0.1	—	—	—
Anomalinidae	5.6	4.7	1.0	2.7	4.1	14.3	3.0	12.9	14.0	16.3	14.6	7.3	5.1	7.8	10.4

sandstone of Werenfels (1926), and Poso series of Anderson (1927), lack exact definition with regard to top and bottom and type section; their type localities can be only partly inferred from the usage of the names.

The section is 5385 meters thick, but extends upward still farther beyond the portion studied. The uppermost 1150 meters is composed of cross-bedded, in part pebbly, coarse to fine, gray to brown sandstones that probably correspond to Beck's (1921) San Antonio formation. They are underlain by 4235 meters of alternating brown shales and ridge-forming massive sandstones, and gray-blue shales. The shales prevail in the lower third (Lower and Middle Oligocene) of the section, whereas the Upper Oligocene and Lower Miocene (excepting the uppermost part of the latter) are essentially sandy (Table 1).

Natural outcrops are weathered to a depth of several feet, and calcareous foraminifera are consequently often leached. Most of the samples were collected from auger holes one to five meters deep, in order to obtain better-preserved fossils. The average stratigraphic interval between samples was 10 meters, with spacing much greater or much less in certain sections. The faunas of 570 localities were studied, but only ninety-five samples were selected for this paper, to illustrate the results. Likewise, only 267 species out of a total of more than 600 are listed in Table 1. They represent the forms that are characteristic or important for their frequency of occurrence and/or for their limited range. New species of little stratigraphic importance were also eliminated, since their description would overstep the limits of this biostratigraphic paper.

BIOSTRATIGRAPHY

The Oligocene and Miocene of the Carmen-Zambrano area have been divided into the following foraminiferal zones:

Middle Miocene (and younger?): *Rotalia beccarii* zonule

Lower Miocene: *Uvigerina subperegrina* zone
Bulimina carmenensis zone

Upper Oligocene: *Sigmoilina tenuis* zone
Siphogenerina basispinata zone
Planulina karsteni subzone
Guttulina caudriae subzone

Middle Oligocene: *Globigerina dissimilis* zone

Lower Oligocene: *Cibicides perlucidus* zone

Upper Eocene (substratum): *Bulimina jacksonensis* zone

This zonation applies to the Carmen-Zambrano area and to most of the Lower Magdalena basin, at least during Oligocene time. During Lower Miocene time, a faunal differentiation took place between the central part of the basin and the Barranquilla area. This was a result of progressive isolation of the former area from the open sea, and of the increased influence of brackish water on the fauna. On the other hand, in the Barranquilla area the Lower Miocene faunas remained under normal conditions.

SUBSTRATUM

The Oligocene shales are underlain by sandstones of Upper Eocene age; the contact between these two formations is gradational in the Carmen area. The Eocene beds consist of well bedded, medium-grained to pebbly, white to gray sandstone containing carbonaceous matter; chocolate-brown sandy shale; and hard, black glauconitic silty shale. Locally, conglomerates and limestones are present. The upper part of this formation contains a characteristic Upper Eocene fauna of smaller foraminifera. Among the main marker species are *Bulimina jacksonensis* Cushman, *Hantkenina alabamensis* Cushman, *Hastigerinella eocenica* Nuttall, and *Spiroplectammina nuttalli* Lalicker.

In unpublished Company reports, Caudri describes a rich assemblage of large foraminifera from the limestones and shallow-water sandy deposits of the same formation:

Amphistegina spp.
Asterocyclina cf. *aster* (Woodring)
Helicolepidina cf. *nortoni* Vaughan
Helicolepidina paucispira Barker and Grimsdale
Helicolepidina spiralis Tobler
Helicostegina? dimorpha Barker and Grimsdale
Helicostegina soldadensis Grimsdale
Lepidocyclina pustulosa Douvillé
Lepidocyclina pustulosa forma *tobleri* Douvillé
Lepidocyclina subglobosa Nuttall
Operculinoides carmenensis (Anderson)
Operculinoides spp.?
Proporocyclina cf. *flintensis* (Cushman)
Rotalia cf. *mexicana mecatepecensis* Nuttall

THE OLIGOCENE-MIOCENE SERIES

Cibicides perlucidus zone

Type section: This zone is defined by the fauna found in the beds west of Carmen to a distance of 3350 meters from the town's church, between localities no. 13572 and 13548 (text-fig. 1). (All distances given in this paper are measured in straight lines.)

Lithology and thickness: The beds containing the fauna of the *Cibicides perlucidus* zone consist of gray-blue foraminiferal shale, grading downward into interbedded shale and sandstone. At the type locality the zone attains a thickness of 1055 meters.

General characteristics of the microfauna: The foraminiferal fauna of the *Cibicides perlucidus* zone is composed of forty-nine genera and approximately 280 species. The lower part of the zone is characterized by the abundance of three families: Lagenidae (17%), Buliminidae (16%), and Valvulinidae (11%) (Table 2). The first family is represented mostly by *Nodosaria* and related genera. The Buliminidae consist predominantly of *Uvigerina*, and the Valvulinidae of the genus *Schenckiella*. The upper part of the zone differs from the lower in the marked increase in the percentage of occurrence of the family Globigerinidae (from 7% to 20%).

In general, the *Cibicides perlucidus* zone is characterized by the overlapping of restricted Oligocene species with species that range up from the Eocene. Among those restricted to the Oligocene, the following are significant:

Anomalina alazanensis Nuttall
Cibicides granulosus Bermudez
Cibicides hettneri Petters and Sarmiento
Cibicides mexicanus Nuttall
Guttulina jarvisi Cushman and Ozawa
Robulus occidentalis torrida Cushman
Schenckiella pallida (Cushman)
Sigmoilina tenuis (Czjzek)
Uvigerina mexicana Nuttall

The species listed below occur in the *Cibicides perlucidus* zone but range up from the Eocene:

Bulimina sculptilis Cushman
Cibicides cookei Cushman and Garrett
Cibicides elegans Bermudez
Cibicides perlucidus Nuttall
Globigerina cf. *bulloides* d'Orbigny, large variety
Globigerina cf. *concinna* Reuss
Globigerina dissimilis Cushman and Bermudez
Globigerina wilsoni Cole(?)
Plectofrondicularia cookei Cushman
Sigmomorphina trinitatensis Cushman and Ozawa
Spiroplectammina zigzag Petters
Textulariella cf. *barretti* (Jones and Parker)
Tritaxilina mexicana Cushman
Uvigerina chirana Cushman and Stone
Uvigerina codazzii Petters and Sarmiento

Cibicides perlucidus Nuttall is much more abundant in the Barranquilla area than at Carmen. There, the zone is also characterized by the common occurrence of *Cibicides cushmani* Nuttall, which is absent at Carmen.

Boundaries: The lower boundary of the *Cibicides perlucidus* zone is marked by the extinction, in the underlying beds, of typical Upper Eocene species such as *Bulimina jacksonensis* Cushman, *Hantkenina alabamensis* Cushman, *Hastigerinella eocenica* Nuttall, and *Spiroplectammina nuttalli* Lalicker, and by the first occurrence of younger species such as *Anomalina alazanensis* Nuttall, *Cibicides granulosus* Bermudez, *Sigmoilina tenuis* (Czjzek), and *Uvigerina mexicana* Nuttall.

The upper limit is defined by the extinction of *Bulimina sculptilis* Cushman, *Cibicides perlucidus* Nuttall, *Schenckiella petrosa* (Cushman and Bermudez), and *Vulvulina chirana* Cushman and Stone, and by the first occurrence, in the overlying *Globigerina dissimilis* zone, of *Cibicides cicatricosus* (Schwager), *Uvigerina* cf. *canariensis* d'Orbigny, *Uvigerina gallowayi* Cushman, and *Uvigerina rustica* Cushman and Edwards.

Age: The *Cibicides perlucidus* zone is of Lower Oligocene age. It overlies definite Upper Eocene beds, but does not contain forms that are limited to the Eocene. The combined presence, in this zone, of species that range from the Upper Eocene into the Middle Oligocene (*Bulimina sculptilis* Cushman, *Globigerina* cf. *concinna* Reuss, *Globigerina dissimilis* Cushman and Bermudez), and of Lower to Middle Oligocene species (*Cibicides mexicanus* Nuttall) limits the age-range of the zone to the Lower and possibly Middle Oligocene (Nuttall, 1933; Cushman and Stainforth, 1945; Stainforth, 1948*a*; Bermudez, 1949, etc.). Nevertheless, the absence of *Uvigerina gallowayi* Cushman and of *Uvigerina rustica* Cushman and Edwards suggests that the age is older than Middle Oligocene, and the presence of *Cibicides perlucidus* Nuttall points further to a Lower Oligocene age (Nuttall, 1933; Stainforth, 1948*a*). Renz (1948) and Bermudez (1949) extend the range of *Cibicides perlucidus* into the Upper Oligocene; it seems to us, however, that their form is different from the original one of Nuttall (1932) and from the one figured by Stainforth (1948*a*) from Ecuador, both of which closely resemble the Colombian species.

The fauna of the *Cibicides perlucidus* zone corresponds to the Lower Oligocene division of Stainforth (1948*a*) in Ecuador. But inasmuch as the upper boundary of the Lower Oligocene in the Caribbean area is not based on pelagic forms, it is possible that it does not always correspond exactly to the same time line.

Relationships: The predominantly shaly beds of the *Cibicides perlucidus* zone pass downward into the underlying sandstone beds of Upper Eocene age with a gradational contact. At Carmen, the upper contact with the Middle Oligocene *Globigerina dissimilis* beds is conformable. In the Barranquilla area, however, the Lower Oligocene is often overlain by the Upper Oligocene.

Environment: The varied fauna of the *Cibicides perlucidus* zone indicates a normal marine neritic environment. An attempt has been made to define the environment better by comparing the fauna with data on living species as published by Bandy (1953), Lowman (1949), Norton (1930), Phleger and Parker (1951), Phleger, Parker and Peirson (1953), and others. Unfortunately, in the Lower Oligocene of the Carmen area there are but few species that are living today. Some of them, such as *Laticarinina pauperata* (Parker and Jones) and *Sigmoilina tenuis* (Czjzek), are deep-water forms. The bulk of the fauna is rather typical of the continental shelf, and indicates an outer neritic environment at depths probably close to 200 meters (the second depth boundary of Phleger and Parker, 1951), in tropical waters at temperatures of about 11° to 13° C.

In the upper part of the zone in the Carmen area, there is a marked increase of pelagic forms (text-fig. 2). Their occurrence probably indicates a deepening of the basin of that area during late *Cibicides perlucidus* time. The same fact has been observed in the Barranquilla area. Nevertheless, the deepening is by no means a general phenomenon in the whole basin. In

other localities, the opposite seems to have taken place. These differential movements probably represent the beginning of a restricted tectonic adjustment in the Lower Magdalena basin which culminated in Middle Oligocene time.

Globigerina dissimilis zone

Type section: The type section of this zone comprises the beds exposed just north of the eastern half of the town of Carmen, between localities no. 13547 and 13525. The top of the zone coincides with the eastern end of the town (text-fig. 1).

Lithology and thickness: At the type section, the beds carrying the *Globigerina dissimilis* fauna consist of hard, dark gray, slightly silty foraminiferal shale, which weathers to a soft chocolate-brown color. The thickness of the zone is 415 meters.

General characteristics of the microfauna: The complete foraminiferal fauna of this zone includes fifty genera and approximately 330 species. The lower part of the zone is marked by an abundance of Globigerinidae, which make up nearly 50% of the total population (Table 2). In the upper part of the zone, the pelagic forms are reduced to 25%, and Buliminidae (18%) and Rotaliidae (11%) become fairly common.

The fauna contains a larger percentage of Oligocene forms than the underlying zone. It is not characterized by any important restricted species, but rather by the absence of forms that are markers either for the overlying or for the underlying beds. There is a faunal change toward the middle part of the zone, which seems to be in accordance with the studies of Stainforth (1948*a*) in Ecuador.

Thus, the top of the lower part of the *Globigerina dissimilis* zone is marked by the extinction of the following species:

Cibicides mexicanus Nuttall
Clavulinoides jarvisi Cushman
Eponides scheibei Petters and Sarmiento
Globigerina cf. *bulloides* d'Orbigny, large variety
Globigerina cf. *concinna* Reuss
Gyroidina multilocula Coryell and Mossman
Plectofrondicularia jarvisi Cushman and Todd(?)
Uvigerina chirana Cushman and Stone

and by the first appearance, in the overlying beds, of:

Cibicides carstensi Cushman and Ellisor
Globigerinoides rubra (d'Orbigny)
Globigerinoides triloba (Reuss)?
Globorotalia "barisanensis LeRoy" of Stainforth (not LeRoy)
Globorotalia cf. *mayeri* Cushman and Ellisor(?)
Gyroidina soldanii altiformis Stewart and Stewart
Planulina renzi Cushman and Stainforth
Schenckiella cyclostomata (Galloway and Morrey)
Siphogenerina transversa Cushman

Other species that are significant, although not necessarily restricted, in the entire *Globigerina dissimilis* zone in the Carmen-Zambrano section are:

Anomalina pompilioides Galloway and Heminway
Cassidulina subglobosa horizontalis Cushman and Renz
Cibicides cicatricosus (Schwager)
Cibicides granulosus Bermudez
Cibicides cf. *sinistralis* Coryell and Rivero
Globigerina dissimilis Cushman and Bermudez
Guttulina jarvisi Cushman and Ozawa
Karreriella subcylindrica (Nuttall)
Parrella culter (Parker and Jones)
Plectofrondicularia angusticostata Cushman
Sigmomorphina trinitatensis Cushman and Ozawa
Uvigerina gallowayi basicordata Cushman and Renz
Uvigerina gallowayi basiquadrata Petters and Sarmiento
Uvigerina mexicana Nuttall
Uvigerina porqueroensis Petters and Sarmiento
Uvigerina redmondi Petters and Sarmiento
Uvigerina rustica Cushman and Edwards
Uvigerina cf. *topilensis* Cushman

Boundaries: The lower boundary of this zone was discussed in connection with the underlying *Cibicides perlucidus* zone. The upper boundary is marked by the extinction of *Globigerina dissimilis* Cushman and Bermudez, *Uvigerina mexicana* Nuttall, and *Uvigerina* cf. *topilensis* Cushman, and by the first appearance, in the overlying beds, of:

Bolivina pisciformis Galloway and Morrey
Candorbulina universa Jedlitschka
Cibicides mantaensis (Galloway and Morrey)
Cibicides matanzasensis (Hadley)
Eponides crebbsi Hedberg
Globorotalia fohsi Cushman and Ellisor
Plectofrondicularia cf. *californica* Cushman and Stewart
Robulus americanus grandis (Cushman)
Robulus melvilli Cushman and Renz
Sigmoilina schlumbergeri Silvestri
Siphogenerina basispinata Cushman and Jarvis
Siphogenerina lamellata Cushman

In the Carmen-Zambrano section, *Globorotalia fohsi* Cushman and Ellisor and *Siphogenerina basispinata* Cushman and Jarvis do not occur in the Middle Oligocene. Nevertheless, in other localities they have been found in the upper Middle Oligocene.

It has been observed in most sections studied in the Lower Magdalena basin that, in the *Guttulina caudriae* subzone, the species *Siphogenerina transversa* Cushman is of common occurrence, whereas in the upper *Globigerina dissimilis* zone it is present, but rarely. Also, the genus *Globigerinoides* is common in the Upper Oligocene, but scarce in the upper part of the Middle Oligocene.

Age: It has been accepted by most micropaleontologists who work in the Caribbean area that the extinction of *Globigerina dissimilis* marks the top of the Middle Oligocene (Stainforth, 1948*a*; Renz, 1948; etc.). In our case, the extinction of this form also corresponds with the first occurrence, in the overlying beds, of the species listed above, most of which are considered to be markers of the Upper Oligocene. As was mentioned before, the lower limit of this zone may, in some cases, not correspond exactly with the Middle Oligocene—Lower Oligocene boundary as defined elsewhere in Tropical America.

Relationships: Neither the top nor the bottom of the *Globigerina dissimilis* zone is marked by lithologic changes in the Carmen-Zambrano area.

Environment: The fauna clearly indicates open-sea conditions. The high percentage of Globigerinidae in the lower part of the zone (text-fig. 2) suggests a fairly deep-water environment, possibly within the bathyal range, at least beyond Phleger and Parker's (1951) second zonal boundary (over 200 meters). The lithology of this interval, composed almost entirely of foraminiferal shales, bears out the environmental determination of this fauna.

It seems, therefore, that there was a gradual deepening of the sea in the Carmen-Zambrano area from the upper Lower Oligocene to the lower Middle Oligocene. In the Barranquilla area, the sea was retreating during or just after Middle Oligocene time, and the Upper Oligocene rests directly on the Lower Oligocene, at least in some sections.

The assemblage of the upper part of the *Globigerina dissimilis* zone indicates somewhat shallower conditions than that of the lower part. Here, the Globigerinidae have been reduced from 50% to 25% of the total population, and genera such as *Bulimina, Uvigerina, Eponides,* and *Gyroidina* have become important constituents of the fauna. Again, not enough species that are still living today are present to make an accurate environmental analysis possible. Nevertheless, the composition of the fauna, and the known depth-ranges of *Bulimina inflata* Seguenza and *Eponides umbonatus* (Reuss), suggest that a fairly deep-water environment and normal open-sea conditions still persisted, on a bottom probably situated close to the edge of the continental shelf (outer neritic to inner bathyal environment).

Siphogenerina basispinata zone

This zone has been divided into two subzones, which are, from bottom to top, the *Guttulina caudriae* subzone and the *Planulina karsteni* subzone. The latter can be subdivided microfaunally into a lower and an upper part.

Guttulina caudriae subzone

Type section: The type section of this subzone comprises the beds present between the east end of the town of Carmen and a point 4500 meters east of the town, on the road to Zambrano (localities no. 13524-13435, text-fig. 1).

Lithology and thickness: At the type section, the lowest part of this subzone lies within the same shale as the Middle Oligocene fauna. The bulk of the beds, however, consists of chocolate-brown shales with occasional sandstone beds and with thick intervals of interbedded silty sandstones, brown shales, and sandy shales. In the Barranquilla area, the corresponding beds consist of light gray-green foraminiferal shale that weathers chocolate-brown. The thickness of the *Guttulina caudriae* subzone in the Carmen-Zambrano section is 930 meters.

General characteristics of the microfauna: A complete list of the foraminiferal fauna of this subzone includes sixty-three genera and approximately 420 species. The fauna, as compared with that of the underlying zone, shows a marked increase in the relative abundance of *Cibicides* and *Siphogenerina* (Table 2). In general, it is characterized by a predominance of Oligocene species, among which the following assemblage is significant:

Anomalina pompilioides Galloway and Heminway
Bolivina imporcata Cushman and Renz
Bulimina rostrata Brady
Candorbulina universa Jedlitschka
Cassidulina carapitana Hedberg

Cassidulina subglobosa horizontalis Cushman and Renz
Cibicides dohertyi Galloway and Morrey
Cibicides mantaensis (Galloway and Morrey)
Cibicides matanzasensis (Hadley)
Cibicides cf. *sinistralis* Coryell and Rivero
Eponides crebbsi Hedberg
Globigerina venezuelana Hedberg
Globigerinoides rubra (d'Orbigny)
Globigerinoides triloba (Reuss)?
Globorotalia "barisanensis LeRoy" of Stainforth (not LeRoy)
Globorotalia fohsi Cushman and Ellisor
Guttulina caudriae Petters and Sarmiento
Gyroidina cf. *parva* Cushman and Renz
Gyroidinoides byramensis campestris (Cushman and Bermudez)
Haplophragmoides wilsoni Howe
Plectofrondicularia angusticostata Cushman
Plectofrondicularia cf. *californica* Cushman and Stewart
Robulus melvillei Cushman and Renz
Robulus wallacei (Hedberg)
Sigmoilina schlumbergeri Silvestri
Siphogenerina basispinata Cushman and Jarvis
Siphogenerina transversa Cushman
Uvigerina auberiana attenuata Cushman and Renz
Uvigerina cf. *canariensis* d'Orbigny
Uvigerina gallowayi Cushman
Uvigerina isidroensis Cushman and Renz

Boundaries: The lower boundary of the *Guttulina caudriae* subzone is characterized by the first occurrence of a host of Upper Oligocene foraminifera, some of which were mentioned in discussing the upper limit of the *Globigerina dissimilis* zone. The upper boundary is marked by the extinction of the following species:

Bolivina advena Cushman
Cassidulina carapitana Hedberg
Cassidulina subglobosa horizontalis Cushman and Renz
Guttulina caudriae Petters and Sarmiento
Gyroidina cf. *parva* Cushman and Renz
Gyroidinoides byramensis campestris (Cushman and Bermudez)
Karreriella subcylindrica (Nuttall)
Pullenia charapotoensis Cushman and Stevenson
Robulus wallacei (Hedberg)
Uvigerina gallowayi basiquadrata Petters and Sarmiento

The upper range-limit of the species listed above may differ slightly elsewhere in the Lower Magdalena basin. For this reason, the boundary between the *Guttulina caudriae* and *Planulina karsteni* subzones is based on the assemblage, rather than on a single species.

Age: This subzone overlies the extinction point of *Globigerina dissimilis* Cushman and Bermudez, which marks the end of Middle Oligocene time in the Caribbean area. It contains an association of *Globorotalia praemenardii* Cushman and *Siphogenerina basispinata* Cushman and Jarvis, which is typical of the Upper Oligocene of the Caribbean area (Stainforth, 1948*a*; Renz, 1948, etc.), but it also contains several species that do not reach the top of the Oligocene (Renz, 1948), for example, *Cibicides matanzasensis* (Hadley), *Siphogenerina transversa* Cushman, and *Uvigerina gallowayi basicordata* Cushman and Renz. Its age is therefore probably lower Upper Oligocene.

Relationships: At Carmen there is no surface evidence to indicate an unconformity at the base of these beds. The upper boundary is also conformable. In the Barranquilla area, this subzone sometimes rests on the Lower Oligocene.

Environment: One of the striking characteristics of the fauna of the *Guttulina caudriae* subzone is the common occurrence of the genus *Siphogenerina*, mainly *S. transversa* Cushman and *S. basispinata* Cushman and Jarvis. Renz (1948) has already noticed this feature in many Oligocene and Miocene sediments in the Caribbean region, and has stated that they constitute a "distinct facies type which might reasonably be called *Siphogenerina* facies." Kleinpell (1938) stated that the costate siphogenerinids are abundant in certain tropical shore-sands, but the genus is not uncommon in "medium-depth" faunas, that is, those down to 500 fathoms in the same area; they seem, however, to favor depths of less than 200 fathoms.

Several of the species present in the fauna of the subzone are still living today. *Cassidulina laevigata carinata* has a depth range from 100 to 700 meters; *Gyroidina soldanii altiformis*, from 200 to 2000 meters; *Nonion pompilioides*, about 200 meters; *Pseudoglandulina comatula*, maximum depth slightly over 200 meters; and *Virgulina pontoni*, generally less than 300 meters (Phleger and Parker, 1951). All this points to an outer neritic environment in a tropical open ocean. The moderate abundance of the genus *Cibicides* also indicates this type of environment (Lowman, 1949).

Planulina karsteni subzone

Type section: The type section of this subzone includes the series of outcrops between a point 4500 meters

east of Carmen and a point 7300 meters east of the same town, on the Carmen-Zambrano road (between localities no. 13432 and 13342, text-fig. 1).

Lithology and thickness: At the type section, the beds that represent the *Planulina karsteni* subzone are composed of strong, ridge-forming, thick massive sandstones with thick interbeds of dark brown to greenish brown foraminiferal shales or interbedded shales, sandy shales and thin sandstones, attaining a thickness of 570 meters. In the Barranquilla area, the contemporaneous beds consist of light gray foraminiferal shales with siltstone concretions.

General characteristics of the microfauna: The foraminiferal fauna of this subzone consists of fifty-eight genera and approximately 380 species. The faunal distribution is similar to that of the underlying subzone, but there is a decrease in the relative abundance of planktonic forms (Table 2) and a corresponding increase in the arenaceous forms, mainly *Schenckiella pallida* (Cushman) and *Sigmoilina tenuis* (Czjzek). The genera *Cibicides, Bolivina, Bulimina,* and *Uvigerina* are of common occurrence, but here, for the first time in the Carmen-Zambrano section, the genus *Bolivina* becomes an important faunal constituent.

Within this division there is a microfaunal break that seems to be of regional importance (Renz, 1948; Stainforth, 1948*a*). This break is marked by the extinction of *Cibicides matanzasensis* (Galloway and Morrey), *Siphogenerina transversa* Cushman, and *Uvigerina gallowayi basicordata* Cushman and Renz, as well as of some forms of more local importance, such as *Anomalina pompilioides* Galloway and Heminway, *Pullenia quinqueloba* (Reuss), and *Uvigerina* "cf. *beccarii* Fornasini" of Renz (not Fornasini).

The following foraminiferal assemblage is considered significant in defining the *Planulina karsteni* subzone:

Bolivina floridana Cushman
Bolivina imporcata Cushman and Renz
Bolivina pisciformis Galloway and Morrey
Bolivina alazanensis Cushman
Bulimina rostrata Brady
Bulimina inflata mexicana Cushman
Bulimina pupoides d'Orbigny
Cibicides cicatricosus (Schwager)
Cibicides dohertyi Galloway and Morrey
Cibicides mantaensis (Galloway and Morrey)
Globigerina venezuelana Hedberg
Globigerinoides rubra (d'Orbigny)
Globigerinoides triloba (Reuss)(?)
Globorotalia "barisanensis LeRoy" of Stainforth (not LeRoy)
Globorotalia fohsi Cushman and Ellisor
Gyroidina soldanii (d'Orbigny)
Nodosaria stainforthi Cushman and Renz
Planulina karsteni Petters and Sarmiento
Pseudoglandulina cf. *comatula* (Cushman)
Sigmoilina schlumbergeri Silvestri
Siphogenerina basispinata Cushman and Jarvis
Trochammina "cf. *pacifica* Cushman" of Renz (not Cushman)
Uvigerina auberiana attenuata Cushman and Renz
Uvigerina cf. *canariensis* d'Orbigny
Uvigerina gallowayi Cushman
Uvigerina isidroensis Cushman and Renz
Uvigerina rustica Cushman and Edwards

Boundaries: The lower boundary of the *Planulina karsteni* subzone was previously discussed, as well as the boundary between the lower and upper parts into which it can be subdivided. The upper boundary is marked by the extinction of *Siphogenerina basispinata* Cushman and Jarvis and *Planulina karsteni* Petters and Sarmiento. The latter form, however, ranges into younger beds in the Barranquilla area.

Age: The foraminiferal fauna of the *Planulina karsteni* subzone includes many species that are Upper Oligocene markers in the Caribbean area, either alone or in assemblages when not accompanied by Middle Oligocene species:

Globigerinoides rubra (d'Orbigny)
Globorotalia "barisanensis LeRoy" of Stainforth (not LeRoy)
Globorotalia fohsi Cushman and Ellisor
Pseudoglandulina cf. *comatula* (Cushman)
Siphogenerina basispinata Cushman and Jarvis
Siphogenerina transversa Cushman
Uvigerina gallowayi Cushman

It is generally agreed that in the Caribbean area *Siphogenerina transversa* Cushman and *Siphogenerina basispinata* Cushman and Jarvis do not reach the top of the Upper Oligocene. Moreover, the overlying *Sigmoilina tenuis* fauna still carries Globorotalias of the *fohsi* group, which are Upper Oligocene markers (Renz, 1948; Stainforth, 1948*a*). For these reasons the *Planulina karsteni* subzone can be considered of Upper Oligocene age, but not as young as the top of the Oligocene.

Relationships: The lower boundary with the *Guttulina caudriae* subzone is apparently conformable throughout the basin. The upper contact with the *Sigmoilina tenuis* zone is conformable in Carmen and generally in the central part of the basin, but on the flanks this subzone is often overlapped by younger beds.

Environment: The faunal assemblage of this subzone is similar to that of the underlying *Guttulina caudriae* subzone. As was mentioned before, the genus *Bolivina* becomes important in the *Planulina karsteni* subzone. Species of this genus occur in both shallow and deep water, but are most common at less than 400 fathoms (Galloway, 1933). Most of the species of *Bolivina* found by Phleger and Parker (1951) in the Gulf of Mexico range downward from very shallow waters, and several show their maximum of abundance between 100 and 200 meters. Also, Lowman's diagrams (1949) point to an abundance of *Bolivina* near the boundary between the neritic and bathyal environments.

The genus *Bulimina* is represented mainly by *Bulimina inflata mexicana* Cushman, which seems to favor fairly deep waters, and *Bulimina pupoides* d'Orbigny, which, according to Brady (1884), ranges from shallow water to 1830 meters. The genus *Uvigerina* is represented by *U. auberiana attenuata* Cushman and Renz, which, according to Phleger and Parker (1951), is especially common between 30 and 300 meters; and by *U. isidroensis* Cushman and Renz and *U. subperegrina* Cushman and Kleinpell, both related to *U. peregrina parvula* Cushman, which was found in the Gulf of Mexico above 200 meters (Phleger and Parker, 1951).

The calcareous fauna thus indicates normal marine conditions at moderate depth, most likely in an outer neritic environment. On the other hand, the moderate abundance of *Schenckiella pallida* (Cushman) suggests somewhat deeper conditions than in the underlying subzone. This form has been found off the California coast at depths of more than 300 meters. *Sigmoilina tenuis* (Czjzek), another common constituent of the fauna, is reported from the Bay of Naples at depths from 200 to 300 meters (Phleger and Parker, 1951).

In summary, the fauna of the *Siphogenerina basispinata* zone in the Carmen-Zambrano area indicates a shallower environment of deposition than that of the underlying *Globigerina dissimilis* zone, but still within the outer neritic range. The conditions were of normal marine sedimentation, probably off a tropical coast. The appearance of coarse clastics in this zone also indicates a shallowing of the sea.

Sigmoilina tenuis zone

Type section: The type section lies along the Carmen-Zambrano road, and includes the series of beds extending from 7300 meters to approximately 10,480 meters east of Carmen (localities no. 13342-13274, text-fig. 1).

Lithology and thickness: The fauna occurs in dark brown to chocolate-brown to greenish brown foraminiferal shales with several interbeds of strong, ridge-forming, massive, thick concretionary sandstones. Their thickness is 400 meters.

General characteristics of the microfauna: The complete foraminiferal fauna of this unit at the type section includes approximately forty-seven genera and 290 species. The typical faunal assemblage is similar to that of the underlying *Planulina karsteni* subzone, but the arenaceous forms are prominent here, constituting, at times, up to 70% of the total population in the middle part of the zone, and up to 25% in its upper part. These arenaceous forms are mainly species of the genera *Cyclammina, Haplophragmoides,* and *Trochammina,* together with *Schenckiella pallida* (Cushman) and *Sigmoilina tenuis* (Czjzek).

Boundaries: The lower boundary of this zone is marked by the disappearance, in the underlying beds, of *Siphogenerina basispinata* Cushman and Jarvis and *Planulina karsteni* Petters and Sarmiento. The upper boundary is marked by the extinction of *Globorotalia "barisanensis* LeRoy" of Stainforth (not LeRoy), *Globorotalia fohsi* Cushman and Ellisor, and *Globorotalia praemenardii* Cushman.

Moreover, the extinction of the following benthonic forms is of importance in limiting this zone in the Carmen area, even though their disappearance in some cases is probably a result of facies, rather than time:

Ehrenbergina caribbea Galloway and Heminway
Eponides ecuadoranus Cushman and Stevenson
Haplophragmoides wilsoni Howe
Parrella culter (Parker and Jones)
Plectofrondicularia cf. *californica* Cushman and Stewart
Uvigerina gallowayi Cushman

Of these forms, *Uvigerina gallowayi* Cushman ranges into the Lower Miocene beds of the Barranquilla area.

In Table 1 it can be seen that numerous forms die out in the *Sigmoilina tenuis* interval. Some of these species probably have time value, while others are controlled by facies. Thus, the best markers of the upper limit of this zone are the *Globorotalia* species mentioned above.

Age: The fauna of the *Sigmoilina tenuis* zone is very closely related to that of the *Planulina karsteni* subzone, and contains a typical Upper Oligocene assemblage. Furthermore, the top is marked by the extinction of the Globorotalias of the *fohsi* group, which is

considered by Renz (1948), Stainforth (1948*a*), and others as a criterion in defining the top of the Oligocene in the Caribbean area. For this reason it is believed that this zone is of uppermost Oligocene age, and correlates with the upper part of the *Globorotalia fohsi* zone of Venezuela and Trinidad.

Relationships: In the central part of the basin, the beds of the *Sigmoilina tenuis* zone are conformable on the underlying zone.

Environment: The lower part of the zone represents an environment very similar to that of the underlying zone. Toward the middle part, arenaceous forms become prominent, indicating a change in environment (text-fig. 2). These forms include the genera *Haplophragmoides* and *Cyclammina*. Lowman (1949) states that *Haplophragmoides* is found associated with *Cyclammina* and *Bathysiphon* in marine deposits in which the mineral and plant components suggest low oxygen content; and he adds: "Therefore, it is clear that this group of bottom-living foraminifera does not characterize any part of the normal profile that extends across open-water environments in well oxygenated conditions. *Haplophragmoides, Trochammina,* and their associates tolerate bottom conditions that the normal assemblage does not tolerate."

On the other hand, the name fossil of the zone, *Sigmoilina tenuis* (Czjzek), seems to favor waters from 200 to 300 meters deep. *Schenckiella pallida* (Cushman), another abundant form in the fauna, seems to favor fairly deep waters. The calcareous fauna is similar to that of the *Planulina karsteni* subzone.

Thus, the faunal assemblage of the *Sigmoilina tenuis* zone points to an outer neritic environment, where the bottom conditions were very probably abnormal, with a low oxygen content. These conditions were probably caused by slow circulation of the waters.

Bulimina carmenensis zone

General statement: During *Bulimina carmenensis* time there was, for the first time, a marked lateral differentiation of the faunas within the Lower Magdalena basin. This was because the basin had become partly land-locked. The *Bulimina carmenensis, Uvigerina subperegrina,* and *Rotalia beccarii* faunas occur within the basin, whereas at its mouth, in the Barranquilla area, wholly different assemblages are present. This paper refers only to faunas of the interior of the basin.

Type section: The type section is on the Carmen-Zambrano road. It is defined as the series of beds lying between locality no. 13273, located 10,480 meters east of Carmen, and locality no. 13185, located 15,500 meters east of the same town (text-fig. 1).

Lithology and thickness: In the type section, the beds that carry the *Bulimina carmenensis* fauna consist mainly of dark chocolate-brown and green foraminiferal shales, with some scattered intercalations of sandy shale and thin, fine sandstone. Their thickness is 500 meters.

General characteristics of the microfauna: The fauna of the *Bulimina carmenensis* zone is composed of forty-seven genera and approximately 150 species. The predominant families in the zone are Rotaliidae (30%), Buliminidae (20%), and Lagenidae (18%) (Table 2). The Rotaliidae consist mainly of *Eponides crebbsi* Hedberg, *Eponides umbonatus* (Reuss), *Eponides ecuadoranus* Cushman and Stevenson, and *Gyroidina venezuelana* Renz. The Buliminidae are made up chiefly of *Bulimina inflata mexicana* Cushman, *Bulimina perversa* Cushman, *Bulimina carmenensis* Petters and Sarmiento, *Uvigerina hispido-costata* Cushman and Todd, and *Uvigerina isidroensis* Cushman and Renz. In the Lagenidae, the genus *Robulus* becomes important.

The following is a selected list of the species occurring in this zone:

Bolivina floridana Cushman
Bolivina imporcata Cushman and Renz
Bolivina cf. *marginata* Cushman
Bolivina pisciformis Galloway and Morrey
Bulimina carmenensis Petters and Sarmiento
Bulimina dentoni Petters and Sarmiento
Bulimina inflata mexicana Cushman
Bulimina perversa Cushman
Cassidulina williami Kleinpell
Cibicides concentricus (Cushman)
Cibicides mantaensis Galloway and Morrey
Eponides crebbsi Hedberg
Globigerina cf. *bulloides* d'Orbigny (small variety)
Globigerinoides triloba (Reuss)?
Globorotalia canariensis (d'Orbigny)
Globorotalia menardii (d'Orbigny)
Gyroidina venezuelana Renz
Haplophragmoides renzi Asano
Nonion costiferum (Cushman)
Planulina ariminensis (d'Orbigny)
Planulina baggi Kleinpell
Planulina "cf. *mexicana* Cushman" of Renz, 1948 (not Cushman)
Planulina subtenuissima (Nuttall)
Plectofrondicularia floridana Cushman

Robulus americanus grandis Cushman
Robulus melvilli Cushman and Renz
Schenckiella pallida (Cushman)
Siphogenerina lamellata Cushman
Sphaeroidina bulloides d'Orbigny
Uvigerina hispido-costata Cushman and Todd
Uvigerina isidroensis Cushman and Renz
Uvigerina subperegrina Cushman and Kleinpell

Megafossils: In the area north of Carmen-Zambrano, beds known from their foraminiferal content to fall within this zone contain, among others, the following megafossil species, identified by F. V. Stevenson (unpublished Company reports):

Architectonica nobilis quadriseriata (Sowerby)
Bursa cf. *crassa colombiana* Weisbord
Conus williamgabbi Maury
Engoniophos erectus (Guppy)
Pleurotoma cf. *vaningeni* Brown and Pilsbry
Polinices prolactea Anderson
Serpulorbis papulosus Guppy
Turris albida Perry
Turritella altilira Conrad
Turritella cartagenensis Pilsbry and Brown
Turritella gatunensis lavelana Hodson
Chama corticosaformis Weisbord
Corbula cf. *viminea* Guppy
Teredo cf. *incrassatus* Gabb

Boundaries: The criteria used in determining the lower boundary of this zone have already been discussed. The upper contact is marked by the extinction of the following foraminiferal species:

Alabamina exigua (Brady)
Bulimina carmenensis Petters and Sarmiento
Bulimina dentoni Petters and Sarmiento
Cassidulina laevigata carinata Cushman
Cibicides mantaensis (Galloway and Morrey)
Eponides crebbsi Hedberg
Planulina ariminensis (d'Orbigny)
Planulina baggi Kleinpell
Planulina "cf. *mexicana* Cushman" of Renz (not Cushman)
Uvigerina isidroensis Cushman and Renz
and others.

In addition to the species listed above, numerous forms die out in the Carmen-Zambrano area toward the close of *Bulimina carmenensis* time (Table 1). The disappearance of many of these species is no doubt a result of the deterioration of living conditions and the change in facies caused by progressive isolation of the basin from the open sea. Nevertheless, the disappearance of some of them has time value. For example, the extinction of *Eponides crebbsi* Hedberg seems to have occurred simultaneously throughout the Caribbean area.

Age: All the megafossils identified from the *Bulimina carmenensis* zone have been recorded from Miocene beds elsewhere. Only one, *Turris albida* Perry, is definitely known to occur in beds considered to be Oligocene in age. Furthermore, as was discussed above, the underlying *Sigmoilina tenuis* zone is of uppermost Oligocene age. The *Bulimina carmenensis* zone therefore belongs to the Lower Miocene.

Relationships: Both the lower and upper contacts of this zone are conformable in the Carmen area.

Environment: Several of the species that are common in the *Bulimina carmenensis* zone are living today. Some of them were found by Phleger and Parker (1951) in the northwest Gulf of Mexico, with the following bathymetric ranges:

Cassidulina crassa d'Orbigny	50 to 200 meters
Cibicides concentricus Cushman	20 to 100 meters
Eponides umbonatus (Reuss)	80 to 3000 meters
Nonion pompilioides (Fichtel and Moll)	above 200 meters
Uvigerina hispido-costata Cushman and Todd	20 to 1000 meters
Uvigerina peregrina parvula Cushman	above 200 meters

Furthermore, according to Lowman (1949), an abundance of Rotaliidae seems to characterize the mid-continental shelf in the Gulf of Mexico. *Robulus,* an important genus in the *Bulimina carmenensis* fauna, is reported by Phleger and Parker (1951) as occurring commonly in the Gulf of Mexico at depths from 50 to 400 meters.

The foraminiferal evidence seems to point to a middle neritic environment for the sediments of the *Bulimina carmenensis* zone, very likely between the first and second depth boundaries of Phleger and Parker (1951) (80 to 200 meters). This statement applies only to the lower and middle parts of the *Bulimina carmenensis* zone; the upper part begins to show the peculiar characteristics of the overlying *Uvigerina subperegrina* zone, which will be discussed below.

Uvigerina subperegrina zone

Type section: The type section is defined as the section lying between localities no. 13174 and no. 13127, situated 10,480 meters and 21,600 meters, respectively, east of the church at Carmen, along the road to Zambrano (text-fig. 1).

Lithology and thickness: At the type section, the *Uvigerina subperegrina* fauna is found in a sequence of interbedded greenish shales, sandy shales, and massive concretionary sandstones. To the east of the Magdalena River, the fauna occurs in less sandy beds. The zone attains a thickness of 365 meters.

General characteristics of the microfauna: The foraminiferal fauna of this zone consists, in the type section, of forty-four forms. The following is a selected list of foraminiferal species occurring in, but not restricted to, the zone:

Bolivina floridana Cushman
Bolivina marginata multicostata Cushman
Bulimina pupoides d'Orbigny
Candorbulina universa Jedlitschka
Cibicides concentricus (Cushman)
Globigerina cf. *bulloides* d'Orbigny, small variety
Globigerinoides triloba (Reuss)
Robulus melvilli Cushman and Renz
Rotalia beccarii (Linné)
Uvigerina subperegrina Cushman and Kleinpell

Megafossils: The following species, determined by F. V. Stevenson, are present, in addition to many forms that could be determined only generically (species restricted to the *Uvigerina subperegrina* zone are marked "×"):

Architectonica nobilis quadriseriata (Sowerby)
Cancellaria cibarcola Anderson
Conus tortuosostriatus Toula
Conus williamgabbi Maury
× *Crucibulum gatunense* (Toula)
Engoniophos erectus (Guppy)
Ficus colombianus Anderson
Hastula cf. *simplex* (Conrad)
Melongena consors Sowerby
Petaloconchus domingensis Sowerby
Polinices prolactea Anderson
Potamides ormei Maury
× *Terebra bowdenensis* Woodring
× *Terebra haitensis* Dall
Terebra ulloa Olsson
Turris albida Perry
Turritella abrupta Spieker
Turritella altilira Conrad
Turritella cartagenensis Pilsbry and Brown
Turritella gatunensis lavelana Hodson
Turritella larensis bayovarensis Olsson
Arca columba Olsson
Arca cor-cupidonis Maury
Arca mirandana Hodson
Asaphis cf. *delicatus* Weisbord
Chama corticosaformis Weisbord
Clementia dariena (Conrad)
Corbula cf. *viminea* Guppy
Corbula vieta Guppy
Scapharca chiriquiensis var. A (Gabb)

Environment: The foraminiferal fauna of this zone is characterized by a notable decrease in the number of species, whereas the number of specimens present in each sample is often great. There is also a marked decrease in the size of the specimens present. These facts are interpreted as having been caused by accelerated deterioration of living conditions, most probably because of the cutting off of the basin from the open sea. It indicates the end of marine conditions preceding the deposition of littoral marine to brackish-water sediments. The foraminiferal fauna of the overlying *Rotalia beccarii* zonule in itself represents such a final stage of the filling-in of the basin.

The upper part of the *Bulimina carmenensis* zone and the *Uvigerina subperegrina* zone therefore represent the first effects of the isolation of the Lower Magdalena basin. The environment was still marine, and the depths of deposition were within the neritic range, probably mid-neritic.

Rotalia beccarii zonule

Type section: This zonule includes all the beds containing the *Rotalia beccarii* fauna, together with the barren overlying beds. The type section is along the Carmen-Zambrano road, between the town of Zambrano and a point 11,650 meters west of it on the road to Carmen (text-fig. 1).

Lithology and thickness: These beds are predominantly cross-bedded, lenticular, coarse to fine-grained sandstones, gray to brown in color. Intercalated shales are well laminated, often sandy and gypsiferous, and gray-brown in color. There are occasional beds of conglomerate and pebbly sandstone. At the type section they attain a thickness of 1150 meters.

General characteristics of the microfauna: The lower beds of this zonule contain a poor and facies-controlled foraminiferal fauna. It consists of abundant *Rotalia beccarii* (Linné), often associated with Miliolidae and rarely with *Amphistegina lessonii* d'Orbigny, a few species of *Globigerina, Nonion commune* (d'Orbigny), *Robulus,* and *Trochammina.* Overlying the foraminiferal section is a barren sequence containing carbonaceous shales and thin coal seams; the next higher sequence of beds is also barren, but contains less carbonaceous matter.

Megafossils: In contrast to the limited microfauna, the megafossil list assembled by F. V. Stevenson (unpublished Company reports) is strikingly rich. Only specifically determined forms are listed below, and only those which are restricted to the *Rotalia beccarii* zonule and overlying beds of the same lithological unit. Most forms listed from the *Uvigerina subperegrina* zone also persist.

Architectonica granulata (Lamarck)
Cancellaria bradleyi Nelson
Cancellaria cibarcola Anderson
Cancellaria islacolonis Maury
Cancellaria laevescens Guppy
Cancellaria rowelli Dall
Conus imitator Brown and Pilsbry
Crucibulum inerme Nelson
Drillia gatunensis Toula
Melongena colombiana Weisbord
Mitra colombiana Weisbord
Natica canrena var. *antinacca* Cossman
Northia? cf. *guttifera* (Grzybowski)
Rissoina cf. *ditomus* Woodring
Rissoina cf. *rituola* Woodring
Solenosteira vaughani medioamericana Olsson
Terebra cirra Dall
Terebra gatunensis Toula
Terebra cf. *pavonia* Olsson
Terebra wolfgangi Toula
Turricula lavinoides Olsson
Turritella gatunensis Conrad
Turritella ocayana var., Merriam
Arca (Anarca) santana santana Loel and Corey
Metis trinitaria colombiensis Weisbord
Ostrea cf. *puelchana* d'Orbigny
Ostrea vaughani cf. *insularis* Pilsbry and Brown
Pitaria cf. *tryoniana* (Gabb)
Cadulus cf. *thallus* (Conrad)

Boundaries: The boundaries are facies-controlled. The lower boundary is discussed under the *Uvigerina subperegrina* zone; the upper boundary is drawn at the complete disappearance of foraminifera.

Age: The megafossils present in the *Rotalia beccarii* zonule indicate an upper Lower Miocene or, more probably, a Middle Miocene age (F. V. Stevenson, unpublished Company reports).

Environment: The foraminiferal fauna of the *Rotalia beccarii* zonule indicates very shallow marine to brackish-water conditions. The megafauna represents a littoral facies, showing a relatively small percentage of brackish-water forms. This megafauna occurs in and north of the Carmen-Zambrano area. To the east of Zambrano, *Cerithium*, *Nerita*, *Dreissensia*, and *Mytilopsis* are indicative of brackish to lacustrine conditions. The faunal and lithologic evidence within the Lower Magdalena basin indicates that the foraminiferal fauna developed under shallow marine to littoral and brackish-water conditions, and that the deposits became wholly continental toward the upper part.

CORRELATION WITH OTHER MICROFAUNAS OF THE CARIBBEAN AREA

Renz (1948) and Stainforth (1948*a*, 1953) have given detailed accounts of the correlation of the Oligo-Miocene faunas of Tropical America. The following discussion is limited to a comparison of the Colombian foraminifera with those of the Agua Salada group of Venezuela and with the fauna of the Cipero marl of Trinidad. In Tables 3 to 6, a comparison of the ranges of foraminifera in various areas is presented. Table 7 is a slightly revised version of Renz's correlation chart (1948, p. 77).

VENEZUELA (STATE OF FALCON)

Guacharaca formation

Renz (1948) gives only a short account of the foraminiferal fauna.

Portion below the Uvigerinella sparsicostata zone: The position immediately above beds bearing *Bulimina jacksonensis*, together with the presence of *Bulimina sculptilis* Cushman, correlates at least part of the Guacharaca fauna with the Colombian *Cibicides perlucidus* zone. Another part of the Guacharaca formation is probably correlative with the lower part of the *Globigerina dissimilis* zone of Colombia (lower Middle Oligocene), since it contains the extinction points of several species that become extinct well within the Middle Oligocene in Colombia (*Uvigerina mexicana* Cushman, etc.). Furthermore, the bottom of the immediately overlying Venezuelan *Uvigerinella sparsicostata* zone is marked by the first appearance of *Siphogenerina transversa* Cushman, which, in Colombia and elsewhere, appears for the first time in the middle of the Middle Oligocene.

Portion containing the Uvigerinella sparsicostata fauna: Renz (1948) considers the *Uvigerinella sparsicostata* fauna of the upper 81 meters of the Guacharaca formation and the lower part of the Agua Salada group as one faunal unit. Since his faunal list comes from the Agua Salada, the correlation with Colombia is discussed in the next paragraph.

Agua Salada group

Uvigerinella sparsicostata zone: Even though Renz (1948) does not mention the presence of *Globigerina*

TABLE 3

CHECK LIST OF FORAMINIFERA COMPARING THEIR OCCURRENCE IN THE

CARMEN-ZAMBRANO SECTION

(BOLIVAR-COLOMBIA) AND IN OTHER PARTS OF THE CARIBBEAN AREA

× Occurrences of satisfactorily determined species
\+ Occurrences of closely related species
? Doubtful occurrences

	COLOMBIA								VENEZUELA																TRINIDAD																								DOMINICAN REPUBLIC				PUERTO RICO						CUBA		
	CARMEN-ZAMBRANO								AGUA SALADA GROUP (EASTERN FALCON)														NE. VENZ.																																																
	UVIGERINA SUBPEREGRINA ZONE	BULIMINA CARMENENSIS ZONE	SIGMOILINA TENUIS ZONE	SIPHOG. BASIS. ZONE	PLANULINA KARSTENI SUBZONE	GUTTULINA CAJORIAE SUBZONE	GLOBIGERINA DISSIMILIS ZONE	CIBICIDES PERLUCIDUS ZONE	LOWER LUCIAN	ROBULUS SENNI ZONE	BASPINULINA SPISTA SUBZONE	BASPINULINA PYRULA SUBZONE	ARAG-UATIAN	VALVULINERIA HENICOENSIS ZONE	GLOBOROTALIA FOHSI ZONE	SIPHOGENERINA TRIGONOSTOMA ZONE	ACOST-IAN	ROBULUS WALLACEI ZONE	ROTALIA SPARSICOSTATA ZONE	CARAPITA SHALE	UPPER ZONE	MIDDLE ZONE	LOWER ZONE	STA CROIX FORMATION	LENGUA CALC. CLAY	CIPERO FMT.	ZONE III	ZONE II	ZONE I	BRASSO FORMATION	NAVARRO RIVER MEMBER	UPPER ZONE	MIDDLE ZONE	LOWER ZONE	TUNNEL HILL MEMBER	UPPER ZONE	LOWER ZONE	ESMERALDA MEMBER	UPPER ZONE	LOWER ZONE	LOWER MIOCENE	UPPER OLIGOCENE	MIDDLE OLIGOCENE	LOWER OLIGOCENE	NORTH SHORE	QUEBRADILLAS FMT	LOS PUERTOS FMT	CIBAO FMT	LARES FMT	SAN SEBASTIAN FMT	PONCE FMT	SOUTH SHORE	FINCA ADELINA MARL	COJIMAR FMT
Allomorphina trigona obtusa Andreae								×																																				×	×																			
Ammodiscus incertus(?) d' Orbigny						×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			+	+	+																													×		
Amphistegina lessonii d' Orbigny	×	×	×	×	×	×			×		×								×					×							×		×			×																						
Anomalina alazanensis Nuttall						×	×	×									×							×			+	+	+																													×		×
Anomalina pompilioides Galloway & Heminway				×	×	×	×	×																			+	×	×																														
Anomalinoides trinitatensis Nuttall						×	×	×			×	×	×	×	×	×	×	×	×					×																																		×		
Astacolus ovatus Galloway & Heminway						×	×	×			×	×					×	×	×					×																																				
Bolivina advena Cushman						×				×	×																																																
Bolivina floridana Cushman	×	×	×	×																																																					
Bolivina imporcata Cushman & Renz			×	×	×	×				×	×	×	×	×	×	×	×	×	×					×							×		×			×																					?
Bolivina marginata multicostata Cushman	×	×	×	×	×	×	×			×	×						×	×	×														×	×																							
Bolivina pisciformis Galloway & Morrey		×	×	×	×	×	×								×	×	×	×						×														×																				
Bolivina cf. tectiformis Cushman					+	+	+	+																				×	×																													
Bulimina impendens Parker & Bermudez								×																																																	
Bulimina cf. marginata d' Orbigny			+																																																						
Bulimina perversa Cushman	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×					×																×	×	×																
Bulimina pupoides d' Orbigny	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×		×			×																×	×	×	×															
Bulimina sculptilis Cushman					?			×																																																	
Candorbulina universa Jedlitschka	×	×	×	×	×																			×		×																															
Cassidulina carapitana Hedberg					×	×	×	×															×	×																																		
Cassidulina crassa d' Orbigny		+	+							×	×	×	×	×	×	×	×	×	×					×			+																																
Cassidulina laevigata carinata Cushman		×	×	×	×	×				×	×	×	×	×	×	×	×	×	×					×																																		
Cassidulina subglobosa Brady	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×		×	×		×				×																														
Cassidulina subglobosa horizontalis Cushman & Renz	×					×	×	×		×	×	×	×	×	×	×	×	×	×					×			×	×	×																														
Cassidulinoides erecta Cushman & Renz		×	×	×	×	×					×			×			×																																									
Ceratobulimina alazanensis Cushman & Jarvis						×	×	×																																																		
Chilostomella ovoidea Reuss	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×					×																																		
Chilostomelloides cf. ovicula Nuttall							+																				×																														
Chrysalogonium elongatum Cushman & Jarvis						×	×	×																																																
Cibicides americanus (Cushman)	+	+	+	+	+	+				×	×	×	×	×	×	×	×	×	×		×	×	×	×							×	×	×	×			×	×																		
Cibicides barnetti Bermudez								×																																																	
Cibicides carstensi Cushman & Ellisor	×	×	×	×	×	×	×			×	×	×	×	×	×	×	×	×	×					×								×																									×
Cibicides cicatricosus (Schwager)					×	×	×																																																
Cibicides cookei Cushman & Garrett					×	×	×																				+	+	+																												
Cibicides elegans Bermudez								×																																																	
Cibicides dohertyi Galloway & Morrey	×	×	×	×	×	×	×																	×																																		
Cibicides granulosus Bermudez							×	×																																															
Cibicides isidroensis Cushman & Renz	×	×								×	×																																												
Cibicides mantaensis (Galloway & Morrey)		×	×	×	×	×							×	×	×	×	×	×	×		×	×	×	×																																	
Cibicides matanzasensis (Hadley)				×	×						×				×	×	×							×																																×
Cibicides mexicanus Nuttall							×	×																			×		×																											
Cibicides perlucidus Nuttall								×									×	×																																					
Cibicides cf. sinitralis Coryell & Rivera					+	+	+	+																																															
Clavulinoides jarvisi Cushman							×	×																																															
Cyclammina deformis Guppy		×	×	×	×	×	×	×																																													
Dentalina consobrina d' Orbigny						×	×	×																																													
Dentalina hilaeformis Galloway & Heminway					×	×	×																																													
Dentalina soluta Reuss			×	×	×	×	×																																														

TABLE 4

CHECK LIST OF FORAMINIFERA COMPARING THEIR OCCURRENCE IN THE

CARMEN-ZAMBRANO SECTION

(BOLIVAR-COLOMBIA) AND IN OTHER PARTS OF THE CARIBBEAN AREA

× Occurrences of satisfactorily determined species

\+ Occurrences of closely related species

? Doubtful occurrences

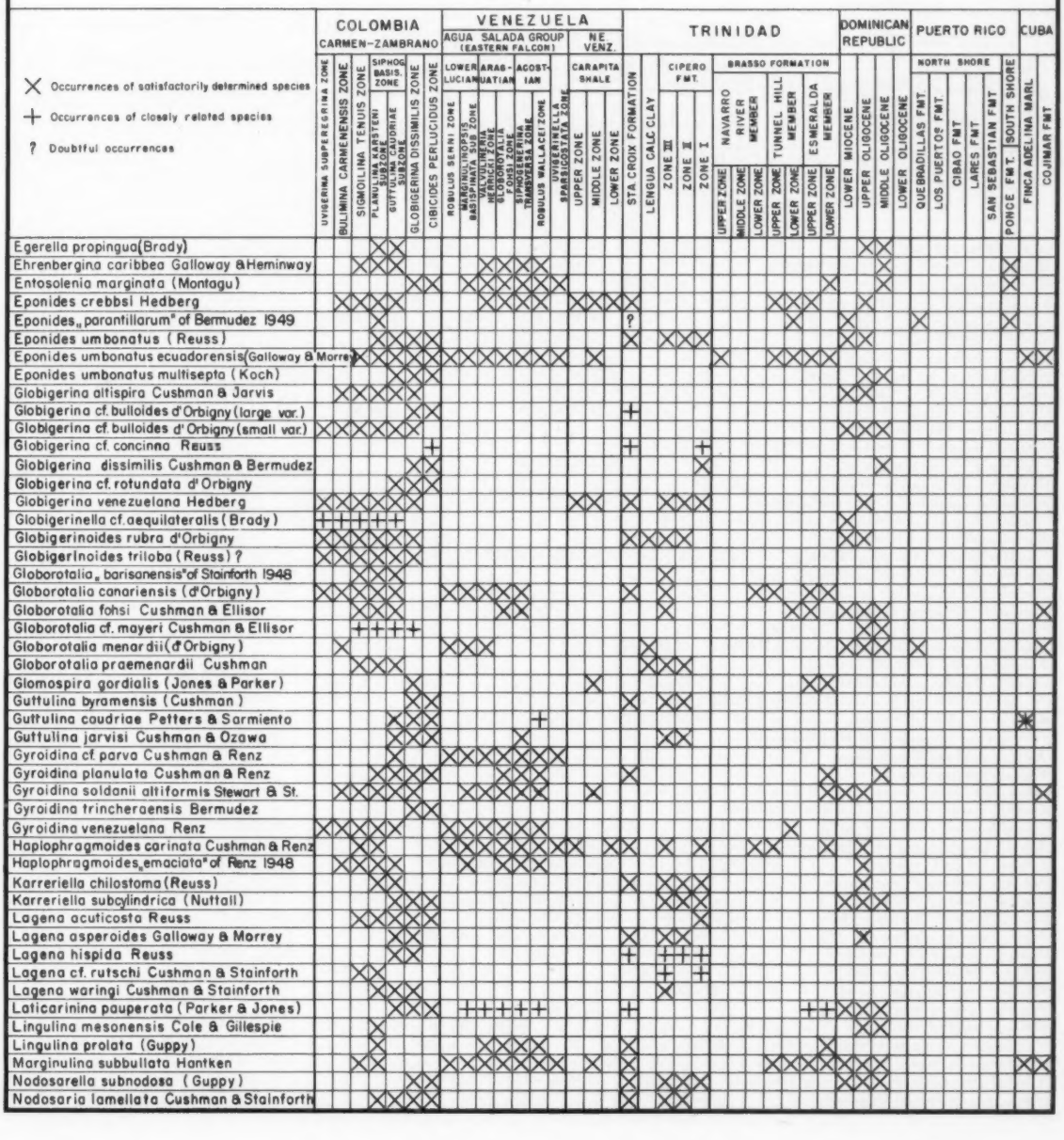


TABLE 5

CHECK LIST OF FORAMINIFERA COMPARING THEIR OCCURRENCE IN THE

CARMEN - ZAMBRANO SECTION

(BOLIVAR-COLOMBIA) AND IN OTHER PARTS OF THE CARIBBEAN AREA

X Occurrences of satisfactorily determined species

\+ Occurrences of closely related species

? Doubtful occurrences

Species	Colombia, Carmen-Zambrano: Uvigerina subperegrina zone	Colombia, Carmen-Zambrano: Bulimina carmenensis zone	Colombia, Carmen-Zambrano: Sigmoilina tenuis zone	Colombia, Carmen-Zambrano: Siphog. basis. zone: Planulina karsteni subzone	Colombia, Carmen-Zambrano: Siphog. basis. zone: Guttulina caudriae subzone	Colombia, Carmen-Zambrano: Globigerina dissimilis zone	Colombia, Carmen-Zambrano: Cibicides perlucidus zone	Venezuela, Agua Salada Group (Eastern Falcon): Lower Lucian: Robulus senni zone	Venezuela, Agua Salada Group: Lower Lucian: Marginulinopsis basispinata sub zone	Venezuela, Agua Salada Group: Araguatian: Valvulineria herricki zone	Venezuela, Agua Salada Group: Araguatian: Globorotalia fohsi zone	Venezuela, Agua Salada Group: Acostian: Siphogenerina transversa zone	Venezuela, Agua Salada Group: Acostian: Robulus wallacei zone	Venezuela, Agua Salada Group: Uvigerinella sparsicostata zone	Venezuela, N.E. Venz., Carapita Shale: Upper zone	Venezuela, N.E. Venz., Carapita Shale: Middle zone	Venezuela, N.E. Venz., Carapita Shale: Lower zone	Trinidad: Sta Croix Formation	Trinidad: Lengua Calc. Clay	Trinidad: Cipero Fmt.: Zone III	Trinidad: Cipero Fmt.: Zone II	Trinidad: Cipero Fmt.: Zone I	Trinidad: Brasso Formation: Navarro River Member: Upper zone	Trinidad: Brasso Formation: Navarro River Member: Middle zone	Trinidad: Brasso Formation: Navarro River Member: Lower zone	Trinidad: Brasso Formation: Tunnel Hill Member: Upper zone	Trinidad: Brasso Formation: Tunnel Hill Member: Lower zone	Trinidad: Brasso Formation: Esmeralda Member: Upper zone	Trinidad: Brasso Formation: Esmeralda Member: Lower zone	Dominican Republic: Lower Miocene	Dominican Republic: Upper Oligocene	Dominican Republic: Middle Oligocene	Dominican Republic: Lower Oligocene	Puerto Rico, North Shore: Quebradillas Fmt	Puerto Rico, North Shore: Los Puertos Fmt	Puerto Rico, North Shore: Cibao Fmt	Puerto Rico, North Shore: Lares Fmt	Puerto Rico, North Shore: San Sebastian Fmt	Puerto Rico, South Shore: Ponce Fmt	Cuba: Finca Adelina Marl	Cuba: Cojimar Fmt
Nodosaria longiscata d' Orbingny			X	X	X	X	X		X	X	X	X	X			X	X	X		X	X	X					X	X	X	X	X	X							X	X	X
Nodosaria raphanistra caribbeana Hedberg					X				X	X	X	X	X		X	X		X								X	X	X	X		X									X	X
Nodosaria spinulosa (Montagu)				X	X	X	X																																		
Nodosaria stainforthi Cushman & Renz	X	X	X	X	X	X	X	X	X	X	X	X	X					X		X	X					X		X	X		X	X							X		
Nodosaria vertebralis (Batsch)				X	X	X			X	X	X	X	X			X		X					X		X	X	X	X		X	X	X									X
Nonion affine (Reuss)			X	X	X	X	X		X	X	X	X	X																X												
Nonion costiferum (Cushman)	X	X	X	X				X	X	X	X	X	X														X														
Nonion incisum kernensis Kleinpell			X	X	X			X	X	X	X	X	X	X	X	X	X						X	X	X	X	X	X													
Nonion pompilioides (Fichtel & Moll)		X	X	X	X	X	X				X	X	X	X						X	X	X				X		X	X	X						X			X		X
Parella culter (Parker & Jones)			X	X	X	X	X		X	X	X	X	X							X	X	X							X		X										
Planularia venezuelana Hedberg			X	X								X	X			X													X			X									
Planulina karsteni Petters & Sarmiento				X	X															+	+																				
Planulina cf. mexicana Cushman		+						+	+	+	+	+	+															+			X	X							+	+	?
Planulina subtenuissima (Nuttall)	X											X	X					X										X	X	X	X									X	X
Plectofrondicularia cf. alazanensis Cushman				+	+																																				
Plectofrondicularia cf. californica Cushman & Stewart			+	+	+							+	+							X	X	X					X	X	X												+
Plectofrondicularia cookei Cushman							X															X																			
Plectofrondicularia floridana Cushman	X	X	X	X	X	X		X	X	X	X	X	X	X				X								X	X	X	X		X										
Plectofrondicularia jarvisi Cushman & Tood						?	?																																		
Plectofrondicularia vaughani Cushman		X	X	X	X							X	X	X		X				X	X	X				X		X			X	X							X	X	
Pleurostomella alterans Schwager					X	X	X					X						+										X	X	X	X	X								X	X
Pleurostomella bierigi Palmer & Bermudez				X								X		X				X		X	X	X							X			X							X	X	
Pleurostomella praegerontica Cushman & Stainforth					X	X	X													X	X	X																			
Pseudoclavulina bullbrooki Cushman				+	+	+	+											X																							
Pseudoglandulina cf. comatula (Cushman)				+	+							X	X					X											X	X	X	X							X	X	X
Pseudoglandulina laevigata ovata (Cushman & Applin)			X	X	X	X	X		X	X	X	X	X	X				X										X	X												
Pullenia bulloides (d' Orbigny)			X	X	X	X	X		X	X	X	X	X	X				X		X	X	X							X	X									X		
Pullenia charapotoensis Cushman & Stevenson					+	+	+																																		
Pullenia multiloba Chapman						X																																			
Pullenia quinqueloba (Reuss)				X	X	X	X											X		X	X	X									X										
Quinqueloculina cf. lamarckiana d' Orbigny			+	+	+	+												+												X											
Quinqueloculina orbiculata Cushman & Stainforth				X																																					
Quinqueloculina seminula (Linne)		X	X							X		X		X										X				X		X	X					X		X			
Robulus americanus grandis Cushman	X	X	X	X	X			X	X	X	X	X	X					X					X	X	X	X		X	X	X	X	X									
Robulus calcar (Linne)		X	X	X				X	X	X	X	X	X		X	X	X	X								X	X	X	X	X	X	X									X
Robulus dicampylus (Franzenau)					X			X	X	X	X	X	X	X						X	X					X	X	X	X					X		X			X		X
Robulus formosus (Cushman)		X							X	X	X	X	X	X															X		X	X								X	X
Robulus melvilli Cushman & Renz	X	X	X	X	X			X	X	X	X	X	X	X											X	X					X										
Robulus occidentalis torrida (Cushman)		X	X	X	X	X	X		X	X	X	X	X	X		X		X		X	X					X	X	X	X										X		
Robulus protuberans (Cushman)					X							X														X	X		X										X		
Robulus rotulatus (Lamarck)				X	X	X	X																																		
Robulus subpapillosus (Nuttall)		X	X	X																											X	X									
Robulus suteri Cushman & Renz		X							X	X	X	X	X					X																							
Robulus wallacei (Hedberg)					X	X							X	X		X												X													
Saracenaria italica carapitana Franklin		X	X	X	X			X		X		X	X					X											X	X	X	X								X	X
Saracenaria schencki Cushman & Hobson		X						+	+	+	+	+	+	+		+					+					+	+	+	+		X	X								+	+
Schenckiella cyclostomata (Galloway & Morrey)			X	X	X	X				+	+	+	+					+										+				X									
Schenckiella nodulosa (Cushman)				X	X																																				

TABLE 6

CHECK LIST OF FORAMINIFERA COMPARING THEIR OCCURRENCE IN THE

CARMEN-ZAMBRANO SECTION

(BOLIVAR-COLOMBIA) AND IN OTHER PARTS OF THE CARIBBEAN AREA

X Occurrences of satisfactorily determined species

\+ Occurrences of closely related species

? Doubtful occurrences

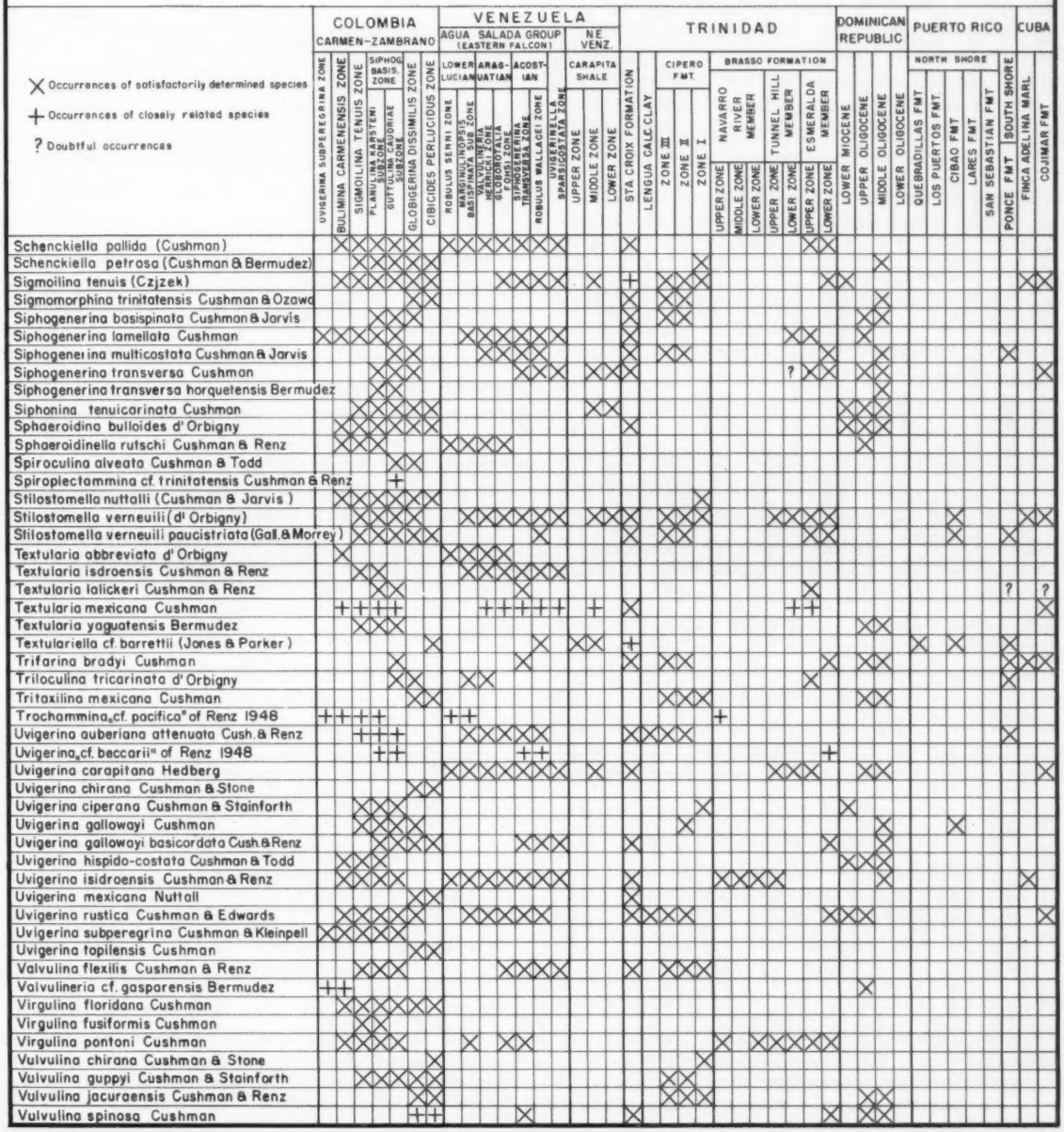
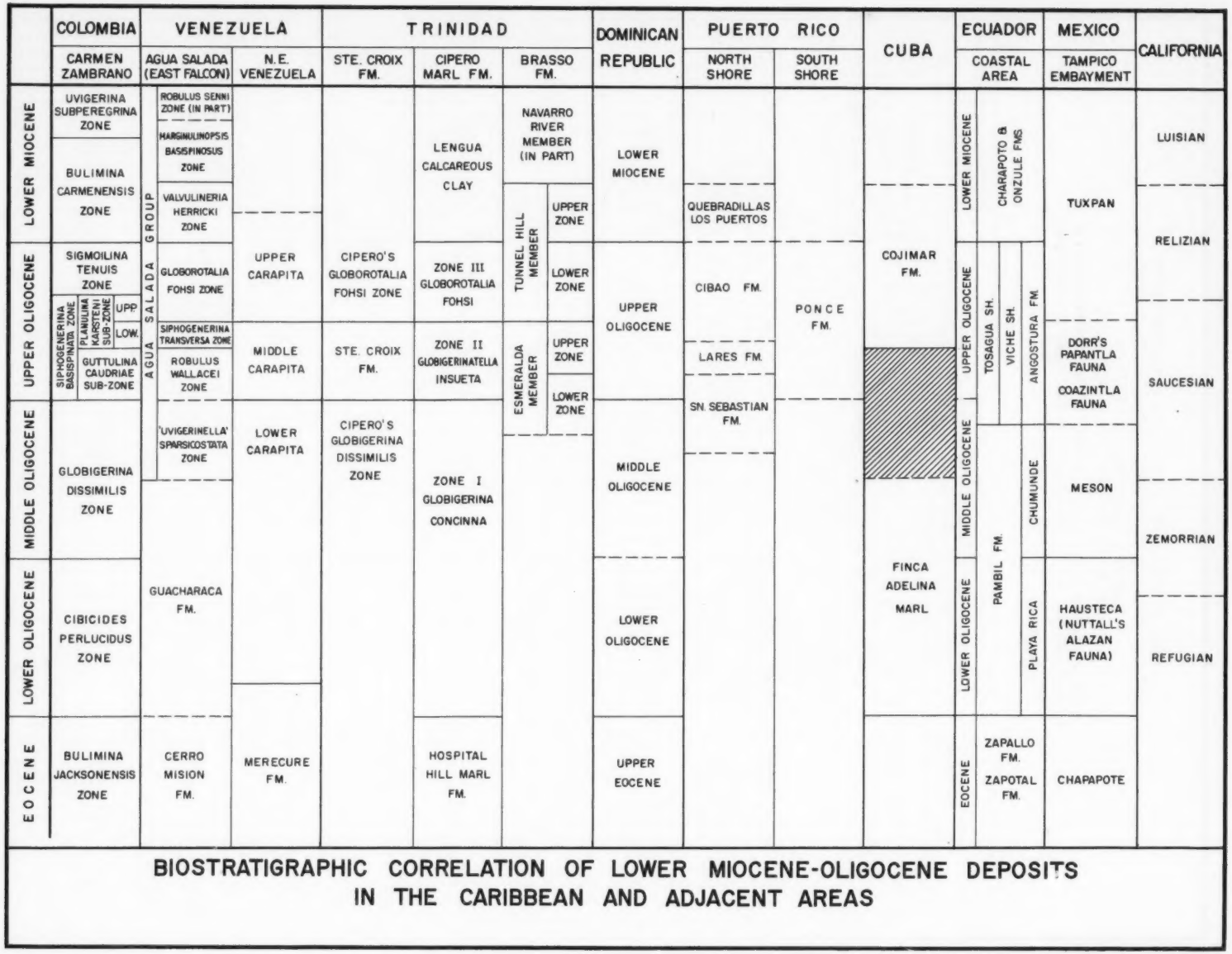


TABLE 7



BIOSTRATIGRAPHIC CORRELATION OF LOWER MIOCENE-OLIGOCENE DEPOSITS IN THE CARIBBEAN AND ADJACENT AREAS

dissimilis Cushman in the *Uvigerinella sparsicostata* zone, the latter can be correlated, in a general way, with the Colombian *Globigerina dissimilis* zone. This is based on the first occurrence of *Cibicides carstensi* Cushman and Ellisor, *Plectofrondicularia floridana* Cushman, *Robulus wallacei* (Hedberg), *Siphogenerina transversa* Cushman, and *Uvigerina gallowayi basicordata* Cushman and Renz at the base of the Venezuelan zone. Very probably it is contemporaneous only with the upper part of the Colombian unit, as explained in the previous paragraph.

Robulus wallacei zone: Robulus wallacei (Hedberg) is rare in Colombia, and *Guttulina caudriae* Petters and Sarmiento is rare in Venezuela, where Renz (1948, pl. 6, fig. 1) calls it *Guttulina irregularis* Reuss. Even these rare occurrences, however, are sufficient evidence for correlating the two faunal zones for which they are name fossils in Venezuela and Colombia, respectively.

In Venezuela, the *Robulus wallacei* zone is subdivided into two zonules. *Uvigerina gallowayi basicordata* Cushman and Renz, the marker of the lower zonule, has a much wider range in Colombia. The upper zonule of Venezuela, characterized by *Planularia venezuelana* and *Saracenaria senni*, and the upper portion of the Colombian *Guttulina caudriae* subzone are marked by the first regular appearance of *Bolivina pisciformis* Galloway and Morrey and *Planularia venezuelana* Hedberg. But the differences in Colombia are not sufficiently clear to warrant a subdivision similar to that of Venezuela.

In addition to the species mentioned above, the following species make their first appearance in both Venezuela and Colombia during this time interval:

Bolivina pisciformis Galloway and Morrey
Cassidulina laevigata carinata Cushman
Cibicides americanus (Cushman)
Ehrenbergina caribbea Galloway and Heminway
Eponides crebbsi Hedberg
Plectofrondicularia californica Cushman and Stewart
Pseudoglandulina comatula (Cushman)
Robulus americanus grandis (Cushman)
Uvigerina auberiana attenuata Cushman and Renz

They support the general correlation of the *Robulus wallacei* and *Guttulina caudriae* faunas.

Siphogenerina transversa zone: The extinction, within this zone, of *Astacolus ovatus* Galloway and Heminway, *Cibicides matanzasensis* (Hadley), *Siphogenerina transversa* Cushman, and *Textulariella miocenica* Cushman is common to this zone and the lower portion of the Colombian *Planulina karsteni* subzone. No further subdivision of this time interval is possible in Colombia, as was done by Renz (1948) for its Venezuelan counterpart.

Globorotalia fohsi zone: This Venezuelan zone correlates with the upper portion of the Colombian *Planulina karsteni* subzone and with the *Sigmoilina tenuis* zone. The upper limit of this time interval corresponds with the widespread Oligocene-Miocene faunal break, which, in the Caribbean region, is marked by a radical change in the planktonic microfauna (extinction of *Globorotalia "barisanensis* LeRoy" of Stainforth (not LeRoy) and of *G. fohsi* Cushman and Ellisor), and by the extinction of some benthonic forms, such as *Liebusella pozoensis* Cushman and Renz and *Textularia isidroensis* Cushman and Renz.

Valvulineria herricki zone: This Venezuelan zone finds its Colombian counterpart in the lower part of the *Bulimina carmenensis* zone. The bottoms of both intervals are marked by the disappearance of the Oligocene planktonic forms mentioned in the previous paragraph, and by the first occurrence of *Globorotalia menardii* (d'Orbigny) and *Planulina* cf. *mexicana* Cushman. The extinction of *Eponides crebbsi* Hedberg, *Robulus suteri* Cushman and Renz, and *Saracenaria italica carapitana* Franklin is common to the top of the *Valvulineria herricki* zone and the higher part of the *Bulimina carmenensis* zone.

Marginulinopsis basispinata zone: This zone seems to correlate with the upper portion of the Colombian *Bulimina carmenensis* zone and with at least the lower part of the *Uvigerina subperegrina* zone. The latter zone, and still more the overlying *Rotalia beccarii* zonule, represent, however, strongly facies-controlled, highly specialized, and reduced faunal assemblages that do not permit wide-range correlation. The following species do not range higher than the *Marginulinopsis basispinata* zone and the two aforementioned Colombian time-equivalents:

Bulimina alazanensis Cushman
Bulimina cf. *costata* d'Orbigny
Cibicides isidroensis Cushman and Renz
Haplophragmoides renzi Asano
Robulus occidentalis torrida Cushman
Virgulina pontoni Cushman

Carapita formation

The Carapita formation was divided by Hedberg (1937, p. 664) into three zones, of which the middle has the richest fauna. The middle zone correlates with

the *Guttulina caudriae* subzone and the lower portion of the *Planulina karsteni* subzone of Colombia. The equivalency of the latter with the top of the middle Carapita is suggested by the extinction of *Siphogenerina transversa* Cushman. This suggests also a correlation of the middle Carapita with the *Siphogenerina transversa* zone of the Agua Salada, whereas Renz (1948, p. 77) correlates it with the *Robulus wallacei* zone only. The bottom of the middle Carapita is not older than the *Guttulina caudriae* subzone of Colombia and the *Robulus wallacei* zone of Venezuela, because of the occurrence of *Cibicides americanus* (Cushman) and *Eponides crebbsi* Hedberg in the upper part of the lower Carapita. Neither species occurs below the Upper Oligocene in the Caribbean area.

The foregoing discussion implies a slight disagreement with Renz (1948, p. 77), who places the entire lower zone of the Carapita in the Middle Oligocene. The oldest occurrence of *Siphogenerina transversa* Cushman falls in the middle portion of the lower Carapita and suggests a correlation of this point with the middle of the Colombian *Globigerina dissimilis* zone (middle Middle Oligocene). The authors follow Renz (1948, p. 77), however, in placing the bottom of the lower Carapita zone within the Lower Oligocene (*Cibicides perlucidus* zone).

Many of the species present in the upper Carapita zone range into the Lower Miocene of Colombia and of the State of Falcón in Venezuela:

Bulimina cf. *inflata* Seguenza
Cassidulina carapitana Hedberg
Cassidulina subglobosa Brady
Eponides crebbsi Hedberg
Globigerina venezuelana Hedberg
Robulus calcar (Linné)

Therefore, the upper Carapita is believed to range in age from Upper Oligocene (upper *Planulina karsteni* subzone) to lowermost Miocene, as the section is divided in Colombia.

TRINIDAD

Cipero marl

The Cipero marl fauna was described by Cushman and Stainforth (1945). It was divided into three faunal zones. The top of the highest zone (III) corresponds in age to the top of the Colombian *Sigmoilina tenuis* subzone, since the extinction of *Globorotalia fohsi* Cushman and Ellisor occurs at the end of both time units.

Zone II of the Cipero cannot be correlated directly with the Carmen-Zambrano area because of the absence of *Globigerinatella insueta* Cushman and Stainforth from the latter section. However, Renz (1948, p. 89) correlates zone II with his lower Araguatian because of the presence of the above-mentioned planktonic species. The lower Araguatian marks the end of the life span of *Siphogenerina transversa* Cushman, and so does the middle portion of the *Planulina karsteni* zone of Colombia. This furnishes an indication of approximate correlation between Colombia and zone II of the Cipero. *Globigerina dissimilis* Cushman and Bermudez becomes extinct at the top of zone I of the Cipero and at the top of the Colombian *Globigerina dissimilis* zone. Zone I includes part of the Lower Oligocene.

SYSTEMATIC DESCRIPTIONS

The holotypes of the new species and variety are deposited in the collections of the Department of Micropaleontology, American Museum of Natural History (A.M.N.H.), New York. Paratypes are deposited in the collections of the U. S. National Museum, Washington, D. C.; the Museo Geologico in Bogotá, Colombia; and the Geologische Bundesanstalt, Vienna, Austria.

Order FORAMINIFERA

Family POLYMORPHINIDAE

Genus GUTTULINA d'Orbigny, 1839

Guttulina caudriae Petters and Sarmiento, new species
Plate 1, figure 1a-c

Guttulina irregularis (d'Orbigny). – RENZ, 1948, Geol. Soc. Amer., Mem. 32, pl. 6, fig. 1.

Test rather high triangular in side view, about one-quarter higher than broad; base nearly flat, edges broadly rounded. Two earlier chambers visible on one side, one chamber visible on the other side, the two earlier chambers extending up two-thirds of the distance to the aperture, the one chamber only to slightly more than half that distance. Apertural view an equilateral triangle, with the two earlier chambers protruding considerably. Sutures depressed very slightly or not at all. Dimensions of holotype in front view: Height 0.99 mm.; width 0.83 mm. Average height 0.76 mm.; width 0.50 mm.

This species closely resembles *Guttulina byramensis* (Cushman) in its flattened base and triangular side and apertural views. It differs, however, in being more slender (height to width index 0.75 to 0.80, compared

with 0.86 to 0.92 in the typical *G. byramensis*). In side view it is very similar to the figure of *Polymorphina inflata* Williamson in Zittel (1876, p. 86, tf. 23, fig. 2, *fide* Ellis and Messina, 1940 *et seq.*), for which, however, neither description nor apertural view is available. *Guttulina semiplana* Reuss lacks the flattened base of *G. caudriae*, and so does *G. problema deltoidea* Reuss, which is also a Middle Oligocene species. The name *deltoidea* suggests a flatter base than is shown in Reuss's somewhat diagrammatic figure, and, if this is true, Reuss's variety could easily be identical with the Colombian species. The figure of *G. irregularis* (d'Orbigny) of Renz (1948, pl. 6, fig. 1) probably represents *G. caudriae*.

Holotype: A.M.N.H., no. FT-1169.

Type level: Sandstone unit, *Guttulina caudriae* subzone of the *Siphogenerina basispinata* zone, lower part of the Upper Oligocene.

Type locality: Intercol loc. no. 13474, 3350 meters east of the church in the town of Carmen, on the road to Zambrano, Department of Bolívar, Colombia.

Remarks: The species is named after Miss C. M. B. Caudri, formerly paleontologist with the Tropical Oil Company.

Family BULIMINIDAE

Genus BULIMINA d'Orbigny, 1826

Bulimina carmenensis Petters and Sarmiento, new species
Plate 1, figure 2a-b

Bulimina elegans d'Orbigny. – BRADY, 1884 (part), Challenger Exped., Rept., Zool., vol. 9, p. 398, pl. 50, figs. 1-2 (not figs. 3-4).

Bulimina parkerae THALMANN, 1942, Amer. Midland Nat., vol. 28, p. 464 (invalid).

Test of medium size, tapering, greatest width near apertural end; triangular in section, especially so in initial portion. Chambers numerous, arranged regularly in four to six whorls, distinct, slightly inflated in the last two whorls; sutures distinct, slightly depressed; wall smooth, finely perforate, sometimes ornamented, especially in the early portion of the test, by about five poorly defined costae. Aperture loop-shaped. Dimensions: Length of type 0.47 mm.; maximum diameter 0.32 mm.

Although it tends to be broader, our species resembles very closely figures 1 and 2, plate 50, of specimens identified by Brady (1884) as *Bulimina elegans* d'Orbigny, but which are not identical with *Bulimina elegans* d'Orbigny, 1826. Our species is different from Brady's figures 3 and 4 of the same plate, mainly in relation to the regular arrangement of the chambers and the triangular cross-section. It also differs in chamber arrangement from *Bulimina baccata* Fornasini, 1901, of which Brady's "*Bulimina elegans* d'Orbigny" has been considered a synonym. Thalmann (1942) proposed for Brady's "*Bulimina elegans*" the name *Bulimina parkerae*, since Fornasini's name is preoccupied by *Bulimina baccata* Yokoyama, 1890. Thalmann's name, however, is considered invalid in accordance with the International Rules of Zoological Nomenclature by Ellis and Messina (1940 *et seq.*), since neither Thalmann nor Brady described these specimens. For these reasons, a new species is here proposed for this Colombian *Bulimina*, restricting it to the description given above, and including Brady's form and Thalmann's in the synonymy.

Holotype: A.M.N.H., no. FT-1170.

Type level: Shale unit, *Bulimina carmenensis* zone, lower part of the Lower Miocene.

Type locality: Intercol loc. no. 13186, on the Carmen-Zambrano road, 15,650 meters east of the church at Carmen, Department of Bolívar, Colombia.

Remarks: The name is derived from the town of Carmen.

Bulimina dentoni Petters and Sarmiento, new species
Plate 1, figure 3a-b

Test small in size, composed of about five whorls, tapering from the widest portion near the top of the last-formed whorl; chambers slightly inflated, increasing regularly in size as added, those of each whorl slightly overhanging the previous ones, only the last-formed ones distinct; sutures distinct in the last whorl; wall ornamented with sharp, blade-like costae, up to fifteen in the circumference of the test, those of each whorl independent of those of adjacent whorls, and projecting backward at their basal ends. Aperture elongate, loop-shaped. Dimensions: Length of type 0.30 mm.; greatest diameter 0.17 mm.

Holotype: A.M.N.H., no. FT-1171.

Type level: Sandstone unit, *Guttulina caudriae* subzone of the *Siphogenerina basispinata* zone, lower part of the Upper Oligocene.

Type locality: Intercol loc. no. 13182, on the Carmen-Zambrano road, 3750 meters east of the church at Carmen, Department of Bolívar, Colombia.

Remarks: The species is named after W. E. Denton, who studied the geology of the Carmen-Zambrano area.

Genus UVIGERINA d'Orbigny, 1826

Uvigerina codazzii Petters and Sarmiento, new species
Plate 1, figure 4a-b

Test elongate, fusiform, greatest width above the middle; initial end bluntly rounded. Chambers strongly inflated; sutures deeply depressed, the later chambers tending to overhang. Wall ornamented with numerous heavy costae, which are not continuous from chamber to chamber, the costae breaking up into short spinose projections toward the base of the test. The strongly inflated chambers and the hispid ornamentation of the base of the test are the main characteristics of this species. The general trend of the costae is longitudinal, but they sometimes make a considerable angle with the axis of the test. Aperture terminal, with a short tubular neck and a slight lip. Dimensions: Length 0.67 mm.; greatest diameter 0.41 mm.

This species resembles *Uvigerina gardnerae* Cushman and Applin var. *cubana* Hadley, but differs from it in the posterior end of the test.

Holotype: A.M.N.H., no. FT-1172.

Type level: Shale unit, *Cibicides perlucidus* zone, Lower Oligocene.

Type locality: Intercol loc. no. 13572, 3350 meters west of the church at Carmen, Department of Bolívar, Colombia.

Remarks: This species is named for A. Codazzi, foremost geographer of Colombia.

Uvigerina gallowayi basiquadrata Petters and Sarmiento, new variety
Plate 1, figure 5a-b

Uvigerina gallowayi Cushman. – BERMUDEZ, 1949, Cushman Lab. Foram. Res., Spec. Pub. no. 25, p. 204, pl. 13, fig. 7.

This variety closely resembles *Uvigerina gallowayi basicordata* Cushman and Renz, but differs from it in the distribution of the spinose ornamentation at the base of the test. In our variety, the ornamentation is formed by much shorter spinose projections, covering the base of the test and giving it a rectangular outline. Dimensions: Length 0.64 mm.; greatest diameter 0.36 mm.

Holotype: A.M.N.H., no. FT-1173.

Type level: Sandstone unit, *Guttulina caudriae* subzone of the *Siphogenerina basispinata* zone, lower part of the Upper Oligocene.

Type locality: Intercol loc. no. 13496, 2500 meters east of the church at Carmen, on the road to Zambrano, Department of Bolívar, Colombia.

Remarks: The varietal name is derived from the characteristic quadrate initial portion of the test.

Uvigerina porqueroensis Petters and Sarmiento, new species
Plate 1, figure 6a-b

Test elongate, greatest width toward apertural end; initial end consisting of a short spinose projection. Chambers in about five whorls, forming a very regular spiral, rapidly increasing in size, the later ones strongly inflated. Sutures depressed, becoming progressively more deeply incised toward the apertural end. Well-ornamented by distinct, plate-like longitudinal costae, twelve to eighteen in the complete circumference of the adult, somewhat unevenly placed, those of each chamber independent, more often than not, of those of adjacent chambers, sometimes projecting backward at the basal end. Aperture terminal, with a very short tubular neck. This species is characterized by the regular spiral arrangement of the chambers and their rapid increase in size, the initial spinose projection, and the plate-like costae. Dimensions: Length 0.69 mm.; greatest diameter 0.37 mm.

Holotype: A.M.N.H., no. FT-1174.

Type level: Sandstone unit, *Guttulina caudriae* subzone, lower part of the Upper Oligocene.

Type locality: Intercol loc. no. 13496, 2500 meters east of the church at Carmen, on the road to Zambrano, Department of Bolívar, Colombia.

Remarks: The name is derived from the town of Porquero, north of the Carmen-Zambrano road.

Uvigerina redmondi Petters and Sarmiento, new species
Plate 1, figure 7a-b

Test elongate, fusiform, periphery lobulate, greatest width at about the middle of the test. Chambers comparatively few and large, strongly inflated, the later chambers becoming loosely arranged, and the last-formed one having a concave inner face; sutures distinct, depressed. Wall rough, granulose. Aperture terminal, with a slender neck. Dimensions: Length of type 0.76 mm.; greatest diameter 0.33 mm.

In shape and size, this species is close to *Uvigerina chirana* Cushman and Stone, but it differs from that species in not having the hispid ornamentation.

Holotype: A.M.N.H., no. FT-1175.

Type level: Sandstone unit, *Guttulina caudriae* subzone of the *Siphogenerina basispinata* zone, lower part of the Upper Oligocene.

Type locality: Intercol loc. no. 13486, on the Carmen-Zambrano road, 2500 meters east of the church at Carmen, Department of Bolívar, Colombia.

Remarks: The species is named after C. D. Redmond, formerly chief paleontologist of the Tropical Oil Company.

Family ROTALIIDAE

Genus EPONIDES Montfort, 1808

Eponides scheibei Petters and Sarmiento, new species
Plate 1, figure 8a-c

Test equally biconvex, sometimes flatter dorsally in young specimens, flatter ventrally in adult specimens. Periphery with acute keel, not lobulate. Ten to eleven chambers in last whorl. Dorsally, whorls very low, only the last two discernible, earlier ones obscured by clear shell material; chambers longer than high, sutures straight, oblique, at about 45° to the spire, slightly limbate but not raised; spiral suture strongly limbate, often forming a distinct step toward the next younger whorl, as in *Eponides abatissae* (Selli); chamber walls irregularly and coarsely perforate. Ventrally, the sutures are very strongly curved, very strongly limbate, less so toward the periphery, and flush with the surface of the test; they form a star-like pattern together with the large umbilical boss, which occupies up to one-quarter of the diameter of the test; the sutures of adult forms are less strongly limbate, and the boss is less well developed; chamber walls nearly smooth, with only a few scattered large pores on the youngest chambers. Aperture a small opening at the ventral base of the apertural face near the periphery. Dimensions: Greatest diameter of type 0.63 mm.; height 0.33 mm. (maximum 1.08 mm. by 0.52 mm.).

Cibicides cookei Cushman and Garrett is similar, but has higher chambers dorsally. Furthermore, it lacks the distinct star-like pattern ventrally and the strong peripheral keel. The latter feature also provides a distinction from *Eponides abatissae* (Selli), which also shows additional openings on the dorsal and ventral chamber walls.

Holotype: A.M.N.H., no. FT-1176.

Type level: Shale unit, *Globigerina dissimilis* zone, Middle Oligocene.

Type locality: Intercol loc. no. 13536, 750 meters northeast of the church at Carmen, Department of Bolívar, Colombia.

Remarks: The name was selected in honor of E. Scheibe, distinguished student of the geology of Colombia.

Family ANOMALINIDAE

Genus PLANULINA d'Orbigny, 1826

Planulina karsteni Petters and Sarmiento, new species
Plate 1, figure 9a-c

Planulina cf. *wuellerstorfi* (Schwager). – CUSHMAN AND STAINFORTH, 1945, Cushman Lab. Foram. Res., Spec. Pub. no. 14, p. 71, pl. 14, fig. 6a-c.

Test large, flat, slightly conical dorsally, very slightly convex to flat ventrally, periphery very slightly lobate, with blunt cord. Nine chambers in last whorl. Dorsally, completely evolute, from four to five whorls clearly discernible; sutures strongly limbate and raised, strongly curved backward, youngest radial sutures starting out from the spiral in a forward direction nearly parallel to the direction of coiling; chamber walls coarsely perforate, younger walls slanting down from the back to the forward end of each chamber, where the posterior septum of the next younger chamber rises abruptly and forms a step-like structure; these younger chambers thus resemble tiles that overlap each other in the direction of coiling. Ventrally, the whorls are very slightly evolute, leaving a small portion of the previous ones visible in a shallow depression; the radial sutures are slightly limbate and raised in the older parts, strongly depressed in the younger parts of the test; they are nearly radial and straight for about half or two-thirds of their length, and then they are bent back at a sharp angle; chamber walls finely perforate. Aperture a low peripheral opening at the base of the last chamber. Dimensions: Greatest diameter of type 1.57 mm.; height 0.32 mm. (average 1.40 mm. by 0.27 mm.).

This species is closely related to *Planulina wuellerstorfi* (Schwager). Cushman and Stainforth (1945, p. 71) compared identical forms from the Cipero marl of Trinidad with Schwager's species. The main difference consists in the fact that the true *P. wuellerstorfi* (Schwager) is slightly more involute dorsally, with the younger whorls covering a small peripheral portion of the previous ones, thus forming a slight depression in the test. In *P. karsteni*, the earlier whorls are left completely uncovered by the later ones up to their periphery; they are flush with the younger whorls, and often form a flat cone with them.

Holotype: A.M.N.H., no. FT-1177.

Type level: Sandstone unit, *Planulina karsteni* subzone of the *Siphogenerina basispinata* zone, middle part of the Upper Oligocene.

Type locality: Intercol loc. no. 13352, 7300 meters east of the church at Carmen, on the road to Zambrano, Department of Bolívar, Colombia.

Remarks: This species is named for E. Karsten, who first described foraminifera from Colombia in 1856.

Genus CIBICIDES Montfort, 1808

Cibicides andersoni Petters and Sarmiento, new species
Plate 1, figure 10a-c

Test stout, small, dorsally only slightly convex, ventrally strongly convex. Periphery with an angular cord, only very slightly lobate or polygonal. Seven or eight chambers in the last whorl. Dorsally, spire completely evolute, inner whorls not clearly discernible, sutures somewhat limbate, only the youngest ones a little raised, only very slightly curved, oblique, and forming rhomboidal chambers, which are as high as they are long; chamber walls perforate. Ventrally, test completely involute, sutures only very slightly limbate but flush with the perforate chamber wall; they join in the umbilical area, where they may form a very small boss of clear shell material; they extend from the umbilicus radially or inclined slightly forward until they reach a point about two-thirds of the distance to the periphery, where they turn abruptly backward, joining the periphery at a very low angle; this curvature of the ventral sutures is less pronounced in young specimens. Aperture a small opening at the base of the last chamber, extending slightly onto the dorsal side of the test. Dimensions: Greatest diameter of type 0.42 mm.; height 0.25 mm. (maximum 0.51 mm. by 0.27 mm.).

This species differs from *C. coryelli* Bermudez in its smaller size, fewer chambers, flatter dorsal side, and the angled ventral sutures; and from *C. heminwayae* Bermudez in its fewer chambers, flatter dorsal side, and the absence of a large ventral boss.

Holotype: A.M.N.H., no. FT-1178.

Type level: Sandstone unit, *Planulina karsteni* subzone of the *Siphogenerina basispinata* zone, middle part of the Upper Oligocene.

Type locality: Intercol loc. no. 13375, 6850 meters east of the church in the town of Carmen, on the road to Zambrano, Department of Bolívar, Colombia.

Remarks: This species is named for F. M. Anderson, who studied the stratigraphy and paleontology of the Tertiaries of coastal Colombia.

Cibicides hettneri Petters and Sarmiento, new species
Plate 1, figure 11a-c

Tests of most specimens completely flat dorsally, only rarely very slightly convex; very strongly convex ventrally; nearly conical, with a fringe on the periphery, which is slightly lobate. Six or rarely seven chambers in last whorl. Dorsally, spire completely evolute; chamber walls flat and flush with the somewhat limbate sutures, only the youngest chambers of very large specimens somewhat inflated and the corresponding sutures depressed; chambers much longer than high, triangular in shape, with nearly straight sutures that are tangential to the spire; sutures glassy, chamber walls finely but densely perforate. Ventrally, spire completely involute, with sutures joining in umbilicus; sutures limbate, more so in their bent portions; they extend radially from the umbilicus and bend forward (often very abruptly) in the fluting between the conical part of the test and the fringe; from there, the sutures turn abruptly backward and join the periphery at a low angle; chamber walls finely but densely perforate. Aperture extending onto the dorsal side, where it is covered by a distinct lip. Dimensions: Greatest diameter of type 0.47 mm.; height 0.20 mm. (maximum 0.61 mm. by 0.25 mm.).

This species closely resembles *Eponides conicus* Boomgaart, except for its definite *Cibicides* type of aperture, its completely flat dorsal side, and its higher chambers. In *C. hettneri*, the height of the chambers in the youngest whorl amounts to about 30 per cent of the corresponding diameter, whereas in *Eponides conicus* Boomgaart, it amounts to only 22 per cent in the type figure.

Holotype: A.M.N.H., no. FT-1179.

Type level: Shale unit, *Globigerina dissimilis* zone, Middle Oligocene.

Type locality: Intercol loc. no. 13536, 750 meters northeast of the church in the town of Carmen, Department of Bolívar, Colombia.

Remarks: The species is named in honor of A. Hettner, who laid the foundations of the stratigraphy of the Eastern Cordillera.

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EXPLANATION OF PLATE 1

1a–c *Guttulina caudriae* Petters and Sarmiento, n. sp.
Holotype, × 30. Sandstone unit, *Guttulina caudriae* subzone, lower part of the Upper Oligocene; loc. no. 13474, on the Carmen-Zambrano road.

2a–b *Bulimina carmenensis* Petters and Sarmiento, n. sp.
Holotype, × 70. Shale unit, *Bulimina carmenensis* zone, lower part of the Lower Miocene; loc. no. 13186, on the Carmen-Zambrano road.

3a–b *Bulimina dentoni* Petters and Sarmiento, n. sp.
Holotype, × 70. Sandstone unit, *Guttulina caudriae* subzone, lower part of the Upper Oligocene; loc. no. 13182, on the Carmen-Zambrano road.

4a–b *Uvigerina codazzii* Petters and Sarmiento, n. sp.
Holotype, × 40. Shale unit, *Cibicides perlucidus* zone, Lower Oligocene; loc. no. 13572, west of Carmen.

5a–b *Uvigerina gallowayi basiquadrata* Petters and Sarmiento, n. var.
Holotype, × 40. Sandstone unit, *Guttulina caudriae* subzone, lower part of the Upper Oligocene; loc. no. 13496, on the Carmen-Zambrano road.

6a–b *Uvigerina porqueroensis* Petters and Sarmiento, n. sp.
Holotype, × 40. Sandstone unit, *Guttulina caudriae* subzone, lower part of the Upper Oligocene; loc. no. 13496, on the Carmen-Zambrano road.

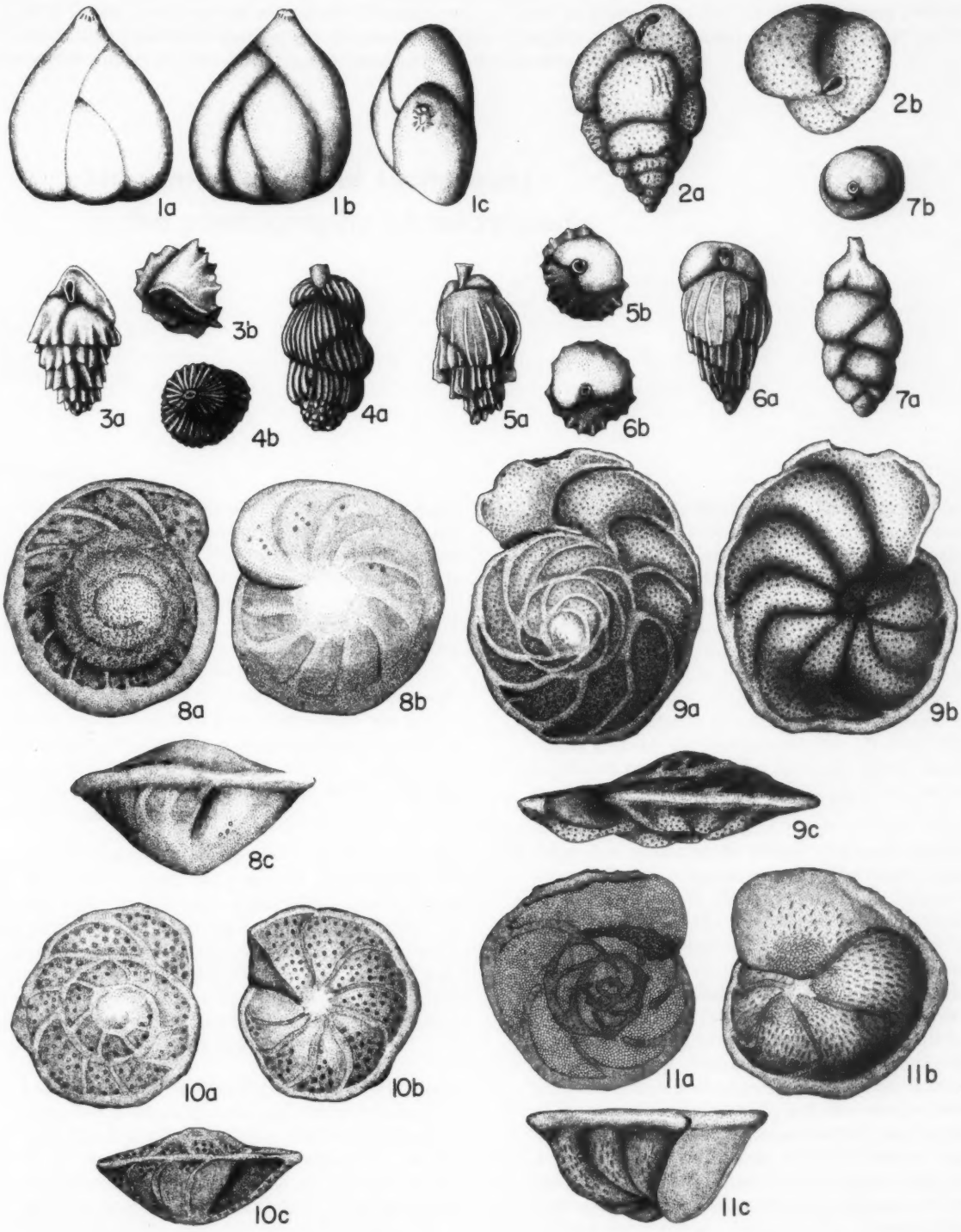
7a–b *Uvigerina redmondi* Petters and Sarmiento, n. sp.
Holotype, × 40. Sandstone unit, *Guttulina caudriae* subzone, lower part of the Upper Oligocene; loc. no. 13486, on the Carmen-Zambrano road.

8a–c *Eponides scheibei* Petters and Sarmiento, n. sp.
Holotype, × 60. Shale unit, *Globigerina dissimilis* zone, Middle Oligocene; loc. no. 13536, on the Carmen-Zambrano road.

9a–c *Planulina karsteni* Petters and Sarmiento, n. sp.
Holotype, × 30. Sandstone unit, *Planulina karsteni* subzone, middle part of the Upper Oligocene; loc. no. 13352, on the Carmen-Zambrano road.

10a–c *Cibicides andersoni* Petters and Sarmiento, n. sp.
Holotype, × 86. Sandstone unit, *Planulina karsteni* subzone, middle part of the Upper Oligocene; loc. no. 13375, on the Carmen-Zambrano road.

11a–c *Cibicides hettneri* Petters and Sarmiento, n. sp.
Holotype, × 60. Shale unit, *Globigerina dissimilis* zone, Middle Oligocene; loc. no. 13536, on the Carmen-Zambrano road.


1a
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ABSTRACT: *The problems involved in the photography of microfossils, especially foraminifera, are presented, and solutions for each problem are suggested. The properties of lenses in general, and the feasibility of using pinhole diaphragms in photomicrography, are discussed in detail. Equipment and techniques recommended for use in photomicrography, including stereoscopic photography, are described.*

New methods and techniques in the photography of microfossils

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INTRODUCTION

Ever since the beginning of work in micropaleontology, the need for adequate means of illustrating microfossils has been felt. A good illustration can reveal more about a specimen than a good description. Although serious efforts have been made by many workers to use photographs in their publications, unfortunately most photographs, if unretouched, do not reveal the details clearly, nor do they give a clear idea of the three-dimensional aspects of the specimen. The unsatisfactory results obtained have discouraged the use of photographic illustrations, and encouraged a return to the use of drawings. The high cost of drawings, in terms of time and money, prevents much valuable material from being published.

In view of this situation, the author decided to make an effort to overcome the principal shortcomings involved in the photography of microfossils. In place of the methods commonly used in other branches of photomicrography, however, special techniques were devised to suit the character of the foraminiferal test, so unique in its structure. The following is a summary of the main difficulties usually encountered in attempting to obtain good photographs:

1) Lack of proper equipment. Efficient equipment exists but is very expensive and has not been simplified and popularized. Most micropaleontologists do not have easy access to such apparatus, nor do they have the necessary time to operate it. Improvised equipment has produced inconsistency of results which has often discouraged workers.

2) Lack of adequate illumination. The main characteristic of most microfossils is that they are three-dimensional and relatively thick. This is especially true of the foraminifera. Their tests approach very closely a polyphasic spherical shape. The problem of showing, in a photograph, all of the details of all of the different faces requires the use of very special lighting. It is necessary to keep in mind at all times the proper distribution of highlights and shadows in order to give an accurate impression of shape and of three-dimensionality. Neither the highlights nor the shadows, however, should be so strong that they obliterate the details of the structures of the test.

3) Improper treatment to reveal structural details. Observation of a specimen under the stereoscopic microscope requires illumination of only moderate intensity. Under the high-intensity illumination necessary for photography, much of the detail of the structure is lost. This loss of detail is often remedied by retouching either the negative or the print. This practice is to be disparaged, even when it is used with the honest intention of emphasizing a feature. Most drawings and retouched photographs of microfossils represent a composite picture of the specimen under study, and very rarely a true image of what was seen at any one time and under a specific set of conditions. Such illustrations are composed of details gathered by repeated observation under a great variety of circumstances, such as wetting the specimen, letting it dry, changing the

magnification, changing from reflected to transmitted light or to a combination of both kinds of light, and so on. It is much better to try to prepare the specimen in such a way that all the observable features appear in the photograph, instead of adding them to the negative or print with pen or pencil.

4) Lack of depth of field. Many of the existing handicaps in the photography of microfossils have their origin in the difficulty of finding objectives with sufficient depth of field. The details on the surface of a foraminiferan lie in a number of parallel planes spaced through the relatively great thickness of the specimen. The low-power objectives of most microscopes have a depth of field that penetrates only a fraction of that space, and consequently are unsuitable for photographic purposes.

5) Unsuitable methods of mounting specimens. In order to save time, most workers attempt to photograph their type specimens on storage slides in which they have already been set in the proper positions, but these slides furnish a poor photographic background. Nothing is so tedious and time-consuming, however, as transferring specimens to another mounting, placing them in the required positions, and then restoring them to their original slides when the work has been done. Consequently, a means of rapidly transferring and setting specimens on a slide with a suitable background had to be devised.

When the attempt to develop a new method of photographing microfossils was begun, it was apparent that success would depend mainly upon whether or not practical ways of overcoming these difficulties could be discovered. One by one they were studied carefully, and a solution for each was found. These solutions are summarized below:

1) The equipment available in most stratigraphic laboratories was found suitable, after certain modifications, except for the binocular microscope. Instead of this instrument, any fairly good monocular can be employed successfully. This is also true of the microscope lamps that are currently in use as standard equipment. The addition of a bull's-eye lens makes these lamps usable for photomicrographic purposes.

2) A study of the structural patterns, distribution of details, and shapes of a large number of microfossils resulted in the use of concentrated beams from three lamps, the use of polarized light, and the application of dark-field illumination. This appears to have solved the problem of illumination.

3) From the point of view of photography, the structures of foraminifera can be grouped into two categories: a) Features present on the surface, which include prominences such as spines, knobs and ridges, and indentations such as pores, apertures, clefts, and sometimes suture lines; b) Features hidden under a smooth, thin layer of semi-transparent material, usually calcite. These are the features that become visible when the specimen is wet. A large number of specimens in group "a" show their external features well under strong illumination, but in many small-sized tests that are very light in color and have very shallow features, the surface characteristics disappear under strong light. The "brown ink technique" has been very successfully applied in this group. The "glycerine technique" has been developed for specimens included in group "b."

4) The use of a small diaphragm, called a pinhole diaphragm, in front of the objective has solved what appeared to be the most unsolvable of the problems relating to the photography of microfossils, that is, to obtain sufficient depth of field to bring into focus all of the details found along the vertical periphery of a foraminiferal test. The 10 × 16 mm. focal-length achromatic objective in itself is not suitable for photographing thick objects (see plate 5). The depth of field of such an objective is only a micrometric plane, but when a 500-micron opening is placed in front of it, such an objective is transformed into one of the most useful tools in photomicrography. Not only is the depth of field increased many times, but, in addition, the inherent optical aberrations of the lens become unimportant.

5) A new method of mounting specimens to be photographed has been developed, which eliminates the time-consuming task of using water-soluble glue to set specimens in position.

As a result of the success obtained with the techniques described in this paper, a new concept of the use of photographs has developed — the idea of true, rather than idealized representation. Many persons prefer that illustrations be "pleasant to look at." Most drawings are much more pleasant to look at than photographs, even though they represent objects that are not inherently beautiful. Although Recent microscopic forms such as foraminifera, ostracodes, and diatoms are characterized by the beauty of their structures, many of the remains of extinct forms are far from beautiful. A Cretaceous foraminiferan that has been buried for millions of years, squeezed, and altered chemically, or whose original material has been re-

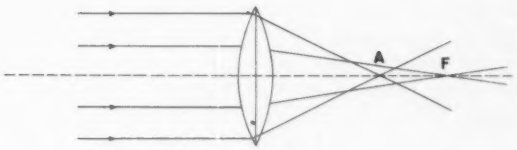
placed, certainly has very little left of its original beauty. Why not try instead to emphasize these "acquired" characteristics, and do everything possible to include them in the illustration? In many instances, illustrations are made or retouched with the idea of partially restoring the original features. The worker who finds a similar specimen and compares it with a retouched illustration expects to find a clear suture line, a pore or an aperture where actually only a distorted feature exists. It is worse yet when the work of retouching cannot be identified as such. A direct comparison of the specimen with the holotype will certainly show that the retouched illustration is misleading, in spite of the fact that it was retouched with the honest intention of clarifying the characters of the holotype.

I am of the opinion that a clearly defined but faint suture line must remain a "clearly defined" faint suture line. Even when ill-defined features are emphasized by means of the "brown ink technique" or the "glycerine technique" described in this paper, mention should be made of such procedures.

The efficiency of the techniques developed has also facilitated a revival of stereoscopic photography, as applied to the study of microfossils. As mentioned before, one of the main characteristics of foraminifera, is the fact that they are three-dimensional. The instrument through which the three dimensions can best be observed is the stereoscopic microscope, standard equipment in all stratigraphic laboratories. The stereopair, which also conveys the idea of depth and thickness, is a graphic representation more nearly like the image seen by a worker using a stereoscopic microscope. Nevertheless, it is very rare to find publications illustrated by stereo-pairs. It may be that the technical difficulties encountered make the method impracticable. With the use of the dark-field illumination described later in this paper, stereo-pairs can be obtained on a single piece of film, just as in taking a single view, simply by moving the specimen from one side to the other and making an exposure first at one end of the film and then at the other. Inexpensive stereoscopes for observing such pairs in three dimensions are available. Measurements of actual thickness are also possible with stereoscopic views.

In spite of the satisfactory results obtained with the methods described here, many of the techniques can be improved. I am confident, however, that many of the difficulties encountered previously have been overcome, and also that many of the suggestions given here will be of help to workers in this field.

The methods and techniques described in this paper are the result of many months of research conducted in the Department of Micropaleontology at the American Museum of Natural History in New York City, under the supervision of Dr. Brooks Ellis and Miss Angelina Messina. These techniques were later perfected at the Stratigraphic Laboratory of the Mene Grande Oil Company, under the direction of Dr. H. H. Renz.



TEXT-FIGURE 1

THEORETICAL CONCEPTS

Aberrations of the objective

It would be impossible to understand the principles that underlie the method to be described here, and the application of the pinhole diaphragm to the objective, without a comprehensive analysis of the possibilities and limitations of the average microscope. The objective is the most important component of a microscope. In it, the resolution of the minute details of the object viewed takes place; such details are not all in one plane but are distributed in different planes through the thickness of the specimen. All of them must be resolved in one plane, yet still retain the impression of depth after being enlarged, perhaps hundreds of times. All lenses suffer from a number of inherent defects. In modern manufacture, most of these defects are eliminated or considerably minimized. Nevertheless, they still hamper good results if they are not understood and corrected. The most important aberrations are:

Axial spherical aberration: Axial spherical aberration consists of the inability of all the light rays that reach the lens to cross exactly at the focal point after being refracted. The use of large openings makes this aberration more conspicuous. In text-figure 1, rays that reach the periphery of the lens cross the axis at *A*, while rays coming from the center cross the axis at *F*. In fact, in a restricted sense, spherical aberration refers only to this longitudinal spreading of the rays. The resultant image is blurred and lacking in detail. This scattering is proportional to the square of the aperture

of the lens, and inversely proportional to the cube of its focal length. The importance of using the smallest possible aperture is obvious.

Coma: The sharpness of the image is further affected by another kind of blurring called coma, which is the result of spherical aberration acting upon an oblique ray. This condition increases rapidly with an increase in the size of the aperture. Here again, the need for the smallest possible aperture is demonstrated.

Curvature of the field: Under the low power of even the most expensive microscope, a piece of paper with minute rectangular patterns always shows curvature of the straight lines, with loss of sharpness as the curvature becomes more pronounced. This effect increases toward the periphery of the lens, and is called curvature of the field, lack of flatness of field, or distortion. Imperfect focus results from the fact that the lens reproduces the straight lines of a flat object as curved lines, concave toward the lens. The component points of a straight line in the object are not all at the same distance from the lens. It is a well-known fact that diaphragming, or reducing the aperture of the lens, produces a flattening of the image because the peripheral oblique rays reaching the lens are blocked by the diaphragm.

Angular aperture

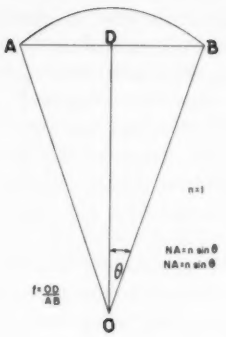
The light-gathering capacity (luminosity) of the lenses used in optical instruments is expressed in different ways. For the lenses used in photographic cameras, the luminosity is expressed in terms of "*f*" values, or relative aperture values. These values represent the focal length of the lens divided by the effective diameter of the objective, or, more accurately, by the diameter of the entrance pupil of the optical system. In text-figure 2, a lens with an effective diameter of *AB* is focused on an object *O*, and the focal length is *OD*. The "*f*" value of such a lens would be

$$f = \frac{OD}{AB}$$

It is obvious that of two lenses of equal effective diameter, the one with the shorter focal length will be the more luminous.

Numerical aperture

For the objectives used in microscopes, the light-gathering capacity is expressed in terms of the numerical aperture (N.A.). It is a constant of the lens, a function derived from the angular aperture and the index of refraction of the medium present between the lens and the object, which may be air, glass, water,



TEXT-FIGURE 2

any of various oils, etc. The N.A. is derived by multiplying the sine of half the angular aperture by the refractive index of the substance through which the observation was made. Mathematically it is expressed:

$$\text{N.A.} = n \sin \theta$$

In text-figure 2, if the medium is air ($n = 1$) then

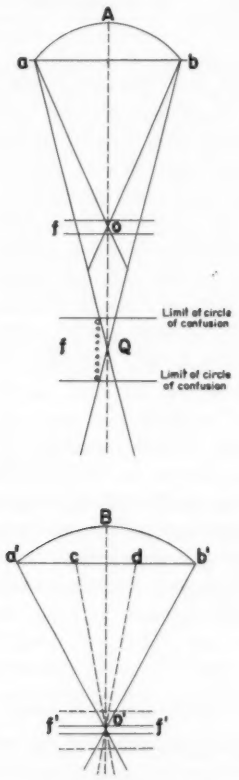
$$\text{N.A.} = \sin \theta$$

The light transmitted by a lens varies as the square of its N.A. value. A lens having twice the N.A. value of another lens transmits four times as much light as the other lens.

Depth of field and circle of confusion

The depth of field, or vertical resolution, depends exclusively on and is controlled by the aperture of the objective. It is independent of focal length or any other lens constant (Shillaber, 1949, p. 55). In theory, the only point, or plane, that is exactly in focus in the object field is the one situated at the apex of the light cone. In practice, there is always a certain distance above and below this point or plane within which details appear to be in focus. Any point lying in the focal plane will be sharply focused by the objective. Points situated immediately above and below the focal plane will also appear to be in focus, although they are really slightly blurred, a fact imperceptible to the human eye. The zone of sharp vision continues to extend away from the critical focal point until a limit is reached at which the eye is able to discriminate the increasingly blurred points, or where the so-called circle of confusion is manifest. This limit is reached when the points acquire a diameter of 1/100 of an inch when viewed at a distance of 10 inches, subtending two minutes of arc or less. The limitations of the human eye are such that points with a greater diameter than that indicated above appear blurred at 10 inches, the normal viewing distance. The space within

the upper and lower limits of the circle of confusion increases as the angular aperture of the lens is increased, provided that the focal length remains constant. The more acute the angle formed by the light cone, the greater the vertical resolution, or depth of field. In text-figure 3, diagrams A and B represent two lenses with the same focal depth. Lens A has a smaller angular aperture than lens B, and a greater depth of field at *O*. If it were possible to increase the focal distance of lens A to *Q*, the depth of field would increase proportionally and would become *f*. Lens B has a very limited depth of field at *O'* when the diameter of the aperture is *a'b'*. If a diaphragm is placed in front of the lens and the aperture becomes *cd*, the acuteness of the light cone increases and the depth of field expands to become *f'*.



TEXT-FIGURE 3

It is important to note that when the aperture of lens B is made smaller in order to achieve greater depth of field, the N.A. of the lens diminishes in value. A decrease in the aperture of the objective also brings about an increase in the contrast of the details and a considerable flattening of the field of view.

Circle of confusion and print size

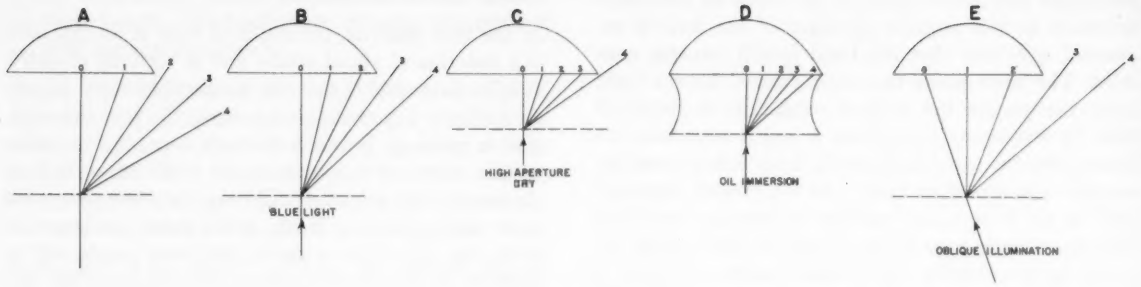
In the final analysis, the depth of field of an objective is a function of visual acuity and of viewing distance. It is understandable that the permissible circle of confusion for a negative depends upon the way the negative is going to be used. If a contact print is made, details made up of points up to 1/100 of an inch in diameter in the negative will be of the same size in the print and will appear sharp. If the print is enlarged to twice the size of the negative, the same points will be 1/50 of an inch in diameter in the enlargement, and they will appear blurred to the eye at 10 inches. In other words, all the images in a negative that are composed of points between 1/200 and 1/100 of an inch in diameter will be blurred in a 2× enlargement, but will remain sharp in a contact print. If enlargements greater than 2× are to be made, the permissible circle of confusion in the negative is decreased further. A 3× enlargement will permit only a 1/300-inch maximum circle of confusion in the negative. The reader can therefore appreciate the advantage of making a negative of the size required for the illustration desired, so that a contact print can be made, with no need for enlargement. There will then be no loss of detail such as occurs when enlargements are made from negatives containing elements on the border line of the permissible circle of confusion. (Farmen, 1942, p. 2266.)

Resolution

The resolution of a lens is its capacity to register small details. The term refers generally to lateral resolution, or to the distance between discrete particles necessary to reproduce separate and distinct images. The resolution of an objective is insufficient when the images of distinct particles are not sharp and blend into one another, forming fuzzy patches. When this happens, there is visibility but not resolution. A line made up of points larger than 1/100 inch, viewed at 10 inches, is certainly visible, but it is not resolved, as its outline will be blurred.

Abbé's theory of image formation

Ernest Abbé (1840-1905) maintained that an opaque particle illuminated by an outside source gives rise to diffracted light rays in addition to the dioptric pencil. In order to form a good image of a microscopic object, an objective must intercept as many of these diffracted rays as possible. The minimum requirements for the resolution of an image are the interception of at least one diffracted ray in addition to a non-diffracted ray,



TEXT-FIGURE 4

as in diagram A, text-figure 4. The perfect image is formed when all the diffracted rays are intercepted by the objective. In diagram A, diffracted ray no. 1 forms the spectrum of the first order, and, together with the non-diffracted ray *O*, produces an image which is resolved. If light of shorter wave length, such as blue light ($\lambda = 405m\mu$), is used with the same objective, the light will be diffracted less, and the second order spectrum can be gathered, as in diagram B, increasing the resolution. It should be remembered that blue light is diffracted less than red ($\lambda = 691m\mu$) or white light (average $\lambda = 555m\mu$). If the aperature of the lens is increased by shortening the focal length, the resolution increases while the depth of field decreases, as in diagram C. In diagram D, the index of refraction of the medium between the object and the lens has been increased by substituting oil for air; four diffracted rays can be gathered by the lens, thus increasing the resolution. In diagram E, the object is illuminated by oblique light, and two diffracted rays are gathered.

The calculation of the resolving power of a microscope is carried out by using high magnification objectives at full aperture and employing transmitted light. The parts of the instrument involved in resolution of the image are the substage condenser and the objective. The N.A. of the system depends upon the N.A. values of both the condenser and the objective, and is expressed by Abbé's equation for resolution (Shillaber, 1949, p. 70):

$$R = \frac{\lambda}{2\text{N.A.}} \qquad [1]$$

in which λ is the wave length of the light used, and 2N.A. may be thought of as the sum of the apertures of the objective and the condenser. When the aperture of the condenser is reduced, or when there is no condenser used, but the source of illumination is a strong and narrow beam reflected from the subject, the N.A. of the condenser is zero or nearly so, and the denominator becomes N.A., leaving the formula

$$R = \frac{\lambda}{\text{N.A.}} \qquad [2]$$

It is evident that, for beams of light of very small angle reaching the objective, the value of *R* is doubled. On the basis of this principle, it seems possible to reduce the aperture of the lens by half, in order to increase the depth of field, and still keep the value of the N.A. of the objective within the limits of good resolution, or, in other words, within the numerical limits of equation no. 1. The diameter of the diaphragm used in front of the lens can not be reduced indefinitely. Its size can not be less than the distance between the optical axis and the point of entrance into the lens of the diffracted ray that forms the spectrum of the first order, or first diffracted ray, because, in accordance with Abbé's theory of resolution, at least one diffracted ray must be included in the formation of the image in order to have resolution. In the photography of microfossils, when very small pinhole diaphragms are used and magnifications over 100× are desired, the use of blue light is recommended in order to improve the resolution (see plate 1, figures 7 and 8). (Shillaber, 1949, pp. 189-199.)

Size of the aperture and intensity of the image

In the previous section, it was shown that the aperture of an objective can be greatly reduced, in order to obtain an increase in depth of field, without reaching the critical limit of resolution. Since the light-gathering capacity of the objective of a microscope is many times greater than that of the fastest photographic lens made (Allen, 1942, pp. 2837-2852), it is also possible to use very small apertures and still retain enough intensity of light to sensitize a film, even at a distance as great as 50 cm. If the N.A. value of the dry lens of

the highest magnification manufactured (N.A. = 0.95) is translated into an "*f*" rating, it is *f*/0.16. The theoretical limit for any photographic lens is *f*/1.0. A microscope objective of the theoretical limit value of N.A. 1 would have a corresponding "*f*" value of 0.02, or 2500 times faster than a photographic objective having a rating of *f*/1.0 (Allen, 1942, pp. 2837-2852). On the basis of this principle, it is possible to reduce the aperture of a microscope objective proportionately, in order to achieve a greater depth of field, to minimum values equivalent to the well-known "*f*" values used in camera work, and still have enough intensity of light to sensitize a photographic plate. Let us consider the 10×, 16 mm. focal-length achromatic objective with N.A. = 0.25. If the diameter of the entrance is reduced to 0.5 mm., its "*f*" value will be

$$f = \frac{\text{focal length}}{\text{diameter of aperture}} = \frac{16}{0.5} = 32$$

Any good photographic objective will produce an adequate exposure with an opening of *f*/32. The N.A. for such an opening is 0.015. An opening 0.25 mm. in diameter is equivalent to *f*/64, and an opening 0.8 mm. in diameter is equivalent to *f*/20. From this point of view, there seems to be no objection to the use of pinhole diaphragms. In fact, sufficient intensity of light passes through a 200-micron diaphragm to project an image intense enough to sensitize a film at a distance of 50 cm., with a total lamp output of 250 watts. (See plate 1, figures 1 and 2, and plate 3, figures 1 to 5.)

The use of pinhole diaphragms

Throughout the previous discussion on theoretical concepts, one point is outstanding, and that is the necessity of using the smallest possible aperture in the photography of microfossils. Exposure speed is not important in this kind of photography. A vibration-proof setup will permit exposures one minute or more in length without noticeable blurring, although such long exposures are very seldom necessary.

The reasons for the use of such small apertures as pinhole diaphragms can be summarized as follows:

1) A small aperture is necessary in order to eliminate or to lessen beyond detection the aberrations present in most objectives, such as axial spherical aberration, coma, and curvature of the field.

2) Chart 1 shows that an objective such as the 10× achromatic with 16 mm. focal length can be equipped with apertures as small as 250 microns and still retain the standard "*f*" values used in ordinary photography. The focal distance of such an objective in microns is 16,000. If this value is divided by the diameter of the aperture, 300 microns, the corresponding "*f*" value so derived is *f*/54. An aperture 500 microns in diameter has a corresponding "*f*" value of 32. Such apertures are within the range of those currently used in ordinary photography (*f*/64, *f*/32, etc.). There is no reason to believe that the intensity of light available through such small openings will be insufficient to sensitize a film.

3) The N.A. values of the apertures indicated above are within the margin required for resolution. The human eye, with an entrance pupil of 2 mm., has an N.A. value of only 0.002. The apochromatic 16 mm. focal-length objective, with an aperture of 0.5 mm., has an N.A. of 0.015, or 7.5 times greater than that of the normal eye. In practice, resolution, or good rendering of detail, depends upon more factors than the N.A. of the objective alone. A great deal also depends upon the source of light, the way it is used, and the quality of the lenses employed.

4) Chart 1 also shows the values of the angle θ for the different openings. The values of the corresponding apertural angles will be 2θ. At full aperture, the 16 mm. objective has a diameter of 5 mm., with an apertural angle of 17°46′. When the 0.5 mm. pinhole diaphragm is used, the angle of aperture is reduced to 1°47′, or about one-tenth as great. With such an aperture, the depth of field increases proportionately and becomes nearly ten times greater. This is exactly what is required in an objective in order for it to be suitable for photographing relatively thick objects such as foraminifera. Perhaps this is the most important feature of the whole procedure in obtaining good photographs of microfossils with the present method.

The diameters of the pinhole diaphragms used for routine work in our laboratory are as follows:

For the 24×,	7.5 mm. achromatic objective	200 microns
" " 10×,	16.0 mm. " "	575 microns
" " 3.5×,	25.0 mm. " "	1425 microns

Comparative results with these three pinhole diaphragms are shown in plate 2, figures 3, 7, and 11; plate 1, figure 3; and plate 4, figures 2, 7, 9, and 10. Magnifications of 400× without making an enlargement from the negative are easily obtained with the 24× objective and an 18× periplan ocular. The objec-

tives listed above, with oculars no higher than 18×, are sufficient to cover the entire range of magnifications necessary to photograph foraminifera.

CHART 1

Achromatic 10×, 16 mm. focal-length objective
N.A. 0.25
with white light (555mμ)

Diameter of pinhole diaphragm	Angle θ	sin θ	Numerical aperture (N.A.)	"f" value
250	0°27′	0.00785	0.008	64
400	0°43′	0.01251	0.012	40
500	0°53′	0.01542	0.015	32
800	1°26′	0.02501	0.025	20
1000	1°47′	0.03112	0.031	16

EQUIPMENT

The equipment employed in the present method can be grouped into three categories: 1) the microscope and optical accessories; 2) the lamps and filters; 3) the bellows assembly and film holders.

The microscope and optical accessories

It has been stated before that one of the purposes of this research project was to study the possibilities of using, for the photography of microfossils, the regular equipment available in a standard micropaleontological laboratory. Any ordinary monocular microscope with well-corrected lenses can be used efficiently. The microscope used by the author is a Leitz monocular equipped with three periplanatic oculars, 8×, 12×, and 25×, and three achromatic objectives, 3.5×, 10×, and 24×. There is an opening between the ocular and the objective in which to insert a polarizing filter that serves as an analyzer when necessary. The objectives are equipped with pinhole diaphragms of the sizes previously indicated. One innovation is the replacement of the fixed stage of the microscope by a rotating stage such as that of a petrographic microscope. Once the specimen is centered in the field of view, it can be rotated on its axis by means of the stage. This procedure materially shortens the length of time necessary to arrange the specimen in position for photography, as compared with rotating the specimen by hand. A graduated mechanical stage is essential for taking stereo-pairs.

The lamps and filters

The light beam used in the present method must be intense and narrow, as cool as possible, and easily shifted in position. The optical quality of the beam should be as close to daylight as possible or may have an excess of blue light. Sources of illumination rich in red light should be avoided.

The carbon-arc lamp, equipped with water cells for cooling the beam, meets these requirements fairly well. Two arc lamps of the clock-feeding type are very satisfactory, although they are not ideal because, in spite of the water cell, a great deal of heat-producing radiation passes through. In our laboratory, the acquisition of two 100-watt Mikrark Illuminators has solved the problem of illumination to our satisfaction. The Mikrark Illuminator is a new departure from the conventional arc lamp. The source of light is an electronic tube with a special target, which is bombarded by a high-tension electronic beam. The target is very small and glows with a cool, very intense light, producing a narrow and even beam. The focusing mechanism consists of optically corrected lenses which allow perfect concentration or spreading of the beam at will, without any rainbow effects. The use of these lamps has saved us many hours of discomfort from heat, and has obviated the constant adjustment necessary when carbon arcs are used. The high quality of light furnished by these lamps greatly simplifies the standardization of the exposure factors, and much film has been saved by cutting down the number of trial-and-error tests.

The filament lamps currently used in laboratories are satisfactory when bull's-eye lenses are employed to concentrate the beam. When this type of lamp is used, it should be equipped with a blue filter in order to suppress the excess red part of the spectrum characteristic of filament lamps.

The bellows assembly and film holders

Any type of bellows that is self-supporting and of moderate extension is satisfactory. It is particularly important that no part of the bellows and film-holder assembly should touch or rest upon the microscope. Any kind of camera that must be supported by the microscope is not recommended. We use the Kodak Precision Enlarger "A," which has the following advantages:

1) It is a self-supporting unit, independent of the microscope.

2) The bellows, film assembly and ground glass constitute a unit that slides up or down on a metal bar; its vertical movement is counterbalanced by a spring, to prevent free fall; the bellows has a separate extension-control knob.

3) It permits the use of 6 × 9 cm. cut film, which is large enough for our purposes, and it also has an adapter for 35 mm. film, with its own ground glass for focusing.

The versatility and solidity of the Kodak Precision Enlarger compensate to a large extent for the shortness of the bellows. Although it would be convenient to have a longer bellows, this is by no means a handicap in the use of the instrument.

It is very important to mount the whole assembly—bellows, film holder and microscope—on a platform resting upon thick sponge-rubber pads on the work table. At the same time, the legs of the table must rest on rubber pads on the floor. All possible precautions to avoid vibration must be taken, including the installation of the equipment away from elevators or other vibration-producing machinery.

It is necessary to insert a shutter between the ocular and the film holder. The shutter of an old camera can serve this purpose if an extension tube wide enough to house the ocular of the microscope is attached to it. The extension tube can be lined with black felt, thus preventing the entrance of stray light.

Critical focusing is of paramount importance. Before any exposure is made, the image on the ground glass must be critically observed and adjusted with the aid of a magnifying glass. Several types of such magnifiers, which can be placed directly on the ground glass, are available.

Determining the size of the image

The size of the image on the ground glass depends upon three factors: 1) the magnification index of the objective; 2) the magnification index of the ocular; 3) the extension of the bellows. With a little practice, the operator will learn to quickly make size-groups of the specimens to be photographed, and to assign to each group the proper combination of ocular and objective for the magnification desired. Factors 1 and 2 become fixed for a given size-group. The only variable factor will be the distance from ocular to plate, which is controlled by the vertical movement of the bellows and film carrier upon their support, when the Kodak Precision Enlarger or a similar apparatus is used. On this support, notches can be cut at points corresponding to the desired magnifications that are possible with a given combination of ocular and objective. In our laboratory, the notches on the verticle support of the Kodak Precision Enlarger were cut as follows: A stage micrometer was chosen as the subject, and a division of 250 microns as the unit. The 8× ocular and the 10× objective were placed in the microscope, and the image of the unit on the ground glass was measured with a millimeter scale until the point of extension was reached where it was enlarged ten times. The first notch on the support was cut at this point. Then the bellows was raised until the image became fifteen times larger than the original, and the next notch was cut. This procedure was continued until the bellows was fully extended. The notches were numbered 1, 2, 3, etc., notch no. 1 corresponding to a magnification of 10×, no. 2 to 15×, etc. The same notches are also used when another combination of ocular and objective is employed to obtain higher magnifications. A chart can be prepared as follows:

CHART 2

Objective 10×

	Film size 6.5 × 9 cm.		Film size 35 mm.
Notch no.	Ocular 8× Magn.	Ocular 12× Magn.	Ocular 8× Magn.
1	10	15	5
2	15	27	10
3	20	38	15
4	25	45	20
5	30	57	25

Calculating the exposure time

The exposure required to obtain good negatives is achieved through experience. Only practice can give uniform results with such variables as magnification, brightness of the subject, etc. It is important to hold constant as many of these factors as possible. For example, once a good exposure technique is developed with a given kind of film and a chosen developer, there is no reason to change either the film or the developer. A wide-latitude panchromatic film is the best type of film that can be used. Panatomic X or Dupont Fine Grain Panchromatic have given us the best results so far. After experimenting with a great many developers, we found that most of them produced a great deal of contrast, with poor detail in the shadows and highlights. The following formula has proved to be the best, when used at a constant room-temperature of 75° F.:

Elon	7.5 gm.
Sodium sulphite	100.0 "
Sodium bisulphite	2.5 "

The developing time at 72° F. is 15 minutes. After a few days of normal use, the developing time increases two or three minutes and remains constant for a long time thereafter. The advantages of this formula are the

following: It does not decompose as rapidly as most of the others; excellent balance of contrast between highlights and shadows is possible, bringing out the details in both; a very fine grain is obtained even when the developer is used at high temperatures; and it does not seem to be sensitive to moderate changes in temperature.

ILLUMINATION REQUIREMENTS

Dark-field illumination

A great deal of consideration has been given to the problem of furnishing a proper background for photomicrographs. After considerable experimentation, a good answer to this problem was found in the use of dark-field illumination. This technique is suitable for all except a few situations, such as, for example, when the specimens are dark gray or black and the outline of the form does not stand out on a black background. Dark gray and black specimens present a difficult problem in photography. Most of the light cast on them is absorbed, and the scant amount reflected is never enough to form a good image. Research on this matter is currently being carried on.

Dark-field illumination is obtained by mounting the specimen on a clean, dust-free glass slide and then placing it over the empty space left by removal of the substage condenser (when a histological microscope is employed). When the three narrow pencils of light from the lamps are focused on the specimen, those rays that do not fall upon the specimen go through the transparent glass slide and into empty space. They cannot be reflected into the objective to produce glare. Since no light enters the objective except that which is reflected by the specimen, the result is a totally black background. Sometimes particles of dust present around the specimen on the glass slide appear in the negative as black dots. Care should be taken to scratch them out before printing.

Photographing microfossils on black cardboard slides has proved to be inefficient. Regardless of how cool the light from the lamps may be, it is always concentrated and of high intensity, and the beam will burn the black paper background of the cardboard slide. In exceptional cases, foraminifera can be photographed on cardboard slides, but very quick action is necessary in order to avoid damage to the slide and possibly to the specimen. Black bakelite and glass slides were tested, but they also proved to be unsatisfactory. There is always some interference from glare. It will be seen later that the dark-field illumination described here is also very satisfactory in photographing stereo-pairs on a single negative.

The three-lamp technique

The problem of properly illuminating an opaque, microscopic three-dimensional form is similar to that of the portrait photographer trying to illuminate a human face, the only difference being in the size of the subject. Microfossils have knobs, cavities, prominences, depressions, curved surfaces, etc., which must be emphasized or minimized, but never obliterated with deep shadows or highlights. They must be balanced proportionately in order to produce a print with the proper rendering of details in black, gray and white tones. In the process of focusing, the image on the ground glass is somewhat deceiving. The pinhole diaphragm increases the contrast of details to a great extent, so that the dark parts appear darker and the highlights much brighter. At this point it should be remembered that the adaptive power of the eye to see detail clearly in spite of contrast is absent from the emulsion of the film, and that a great deal of the detail observable on the ground glass will be lost unless the proper balance of illumination is achieved. Specimens illuminated from opposite sides by two lamps of equal intensity appear on the ground glass to be fairly well illuminated. The eye sees details in the shadows which the emulsion cannot record. Such areas will appear in the negative as black blotches unless a third lamp is used, which we call the "shadow softener." A low-voltage, high-intensity adjustable-beam lamp, such as the American Optical Company 30-watt, 6- to 8-volt lamp, is very suitable. This third lamp must be maneuverable, so that it can be placed anywhere around the stage of the microscope. While the two main lamps remain more or less stationary, the shadow softener, the intensity of which can be changed at will by means of a rheostat, serves to correct excessive contrast by illuminating the deep shadows.

The use of polarized light

Stray reflections produced by highly polished surfaces of hyaline and porcelanous tests will dot the image of the specimen with undesirable white spots. Light reflected from these surfaces is, for the most part, polarized; it vibrates in single planes at various angles. By the interpolation of a polarizing screen between the ocular and the shutter, a large percentage of these reflections can be eliminated. The screen is rotated to the most desirable position, which is at right angles to the plane of vibration of the greatest number of polarized rays. It will be observed that a large number of glaring spots will disappear completely, while others will diminish in intensity. It is always necessary for

some of the spots to show in the final print, in order to produce the impression of a shiny surface, but not so many as to obscure the details of the specimen. When the polarizing screen is used, the exposure should be increased in accordance with the filter factor of the screen as stated by the manufacturer. Only high-quality polarizing filters should be used, to avoid loss of detail and of intensity.

In our laboratory, each of the two Mikrark lamps has been equipped with a Polaroid filter mounted at the end of an insulated metal tube that fits into and rotates freely in front of the optical system of the lamp. The light from the lamps is thus polarized. The beam from one lamp alone is allowed to fall upon the specimen, and the tube holding the polarizer is then rotated until the position is found at which most of the glare disappears. The same procedure is then followed with the other lamp. It has been observed that in most cases it is not necessary to use the polarizing screen in the microscope, which acts as an analyzer, because the use of polarized light alone is sufficient to eliminate most of the glare. The analyzer is used only in extreme cases, when an absolutely glare-free negative is desired (see plate 1, figures 10 to 12). In such cases, the use of both the polarizers and the analyzer causes a substantial loss in light intensity that must be compensated for by increasing the exposure time proportionately.

PREPARATION OF THE SPECIMEN

The "Stay Flat" slide

This peculiar name has been given to a time-saving device for temporarily mounting microfossils to be photographed. "Stay Flat" is the trade name for a non-drying gelatine-like glue, nearly transparent, normally used in photographic work to hold large-sized acetate films flat against the back of the camera. In our method, a few drops of "Stay Flat" are poured over a clean glass slide, and the slide tilted successively in various directions in order to spread the liquid evenly over the whole surface. The liquid is allowed to gel for 15 minutes, and then is ready for use. The specimen is taken from the cardboard slide wet, and placed under the microscope on a small piece of blotting paper. One or two drops of water will wash off any glue that may be adhering to the specimen. The specimen will dry almost immediately, and a slightly moistened brush will pick it up readily. The blotting paper is replaced on the stage by the "Stay Flat" slide, and the dry specimen is placed upon it. The brush is not used to correct the position of the specimen. A steel needle is preferable for this operation. Care must be taken to handle the specimen with a very light touch, so as not to bury it in the glue. It takes only a few seconds to place even a very "top-heavy" foraminiferan on edge or on end, in order to photograph its aperture. To remove the specimen, free of glue, from the "Stay Flat" slide, a drop of water is applied with the brush. If some glue sticks to the specimen, which is usually a result of rough handling, place it on a glass slide and apply a few drops of 95% alcohol, which will solidify the glue and make its removal easy. Care should be taken to keep "Stay Flat" slides under cover so that dust will not collect on them. If this happens, they will very soon become useless through loss of adhesiveness.

The "glycerine technique"

In the observation of microfossils under the microscope, the practice of wetting the specimen has become an integral part of the technique. Wet specimens are more transparent, and certain structures, such as sutures, orifices, etc., ordinarily invisible just beneath the wall, become visible. The results of the observation are usually given as a summary of the features visible under both dry and wet conditions. Most drawings of microfossils incorporate elements derived from both techniques of observation, and represent a more or less idealized picture of any one specimen. Photographs are most realistic, since they show better how a specimen looks under a particular set of conditions. A photograph of a dry specimen actually shows how it looks when dry. Another photograph of the same specimen when wet will reveal the features visible under this condition, and will also show clearly that the specimen was under a liquid when the photograph was taken. Any discriminating observer will find it possible to make identifications much more rapidly when truly representative photographs are available.

For the purpose of photographing a specimen wet, glycerine is preferable to water. Glycerine has a higher index of refraction ($n = 1.473$) than water ($n = 1.332$), and therefore produces greater contrast. The higher degree of viscosity of glycerine inhibits the formation of convection currents resulting from the heat produced by the strong light, so that the specimen will remain fixed in position during the exposure of the film. In addition, glycerine does not evaporate as rapidly as water, and can be washed out with a few drops of water before the specimen is returned to the storage slide.

The specimen is placed in position, either on a clean glass slide or on a "Stay Flat" slide, and a good-sized drop of glycerine is applied to it. The glycerine

spreads evenly around it, and any air bubbles can be cleared with the brush. The viscous liquid does not always displace the air bubbles from the chambers of foraminifera. A drop of water will do this, however, and after excess water has been removed with a dry brush, another drop of glycerine is applied.

The amount of light reflected by a specimen under a liquid is considerably less than that reflected by the dry specimen. It is therefore necessary to increase the length of the exposure two to four times, depending upon the color and degree of transparency of the subject. Sometimes better results are obtained by placing a cover slip over the specimen, which can be done only when the "Stay Flat" slide is not used. The cover slip is placed on the slide on one of its edges, and allowed to fall so that it will cover the specimen. To remove the specimen without losing it, the cover slip is gently pushed laterally until part of it is off the edge of the slide, and then it is carefully lifted. The specimen will be found in the glycerine left on the slide. Photography in glycerine requires the use of the maximum intensity of light available. The lamps should be placed low, at an angle of about 15° to the plane of the stage. The even diffusion of light through the glycerine illuminates the specimen evenly, so that no highlights or shadows are produced, and the resulting appearance is flat, giving no impression of roundness. A photograph taken in glycerine is to some extent like an X-ray view of the specimen, revealing structures present just beneath the semi-transparent wall. Such pictures should always be complementary to a photograph taken under dry conditions. (See plate 2, figures 1, 2, 5, 6, and 9 to 12.)

The "brown ink technique"

In a great variety of foraminiferal tests, the surface features are very shallow, or the material of the test is quite transparent, or both. When the lamps are focused on such specimens, some of the small pores, faint suture lines, and similar features are not visible on the ground glass. It may happen, in addition, that some of the straight-line structures fall parallel to the light beams, and do not cast any shadows to make them conspicuous. In such cases it is desirable to emphasize these features. A very efficient method is to fill them with a dark pigment that can be easily removed later on. Scheaffer's "Skrip" washable brown ink no. 12 or Carter's washable brown ink have proved to be satisfactory. The pigment in these inks seems to be extremely fine, and, when applied, concentrates in the hollow features, creating striking contrast between high and low structures. The brown residue sometimes reveals otherwise unobservable structures. (See plate 1, figures 4 and 5, and plate 2, figure 7.)

A few light touches with a brush moistened in the ink are sufficient to cover the surface of the specimen without actually saturating it. The specimen is then permitted to dry. If an excess of ink has been used, it can be removed readily with a brush moistened with water. When the specimen is to be returned to the storage slide, a drop of water will quickly wash it clean.

The staining of microfossils with silver nitrate is not recommended. Such a stain is not selective and is permanent. The metallic luster left on the specimen produces bright spots, and the color imparted is so dark that most of the light is absorbed by the specimen.

STEREOSCOPIC PHOTOGRAPHY

Technique for making stereoscopic pairs

This method of taking stereo-pairs is rather simple. Two things are required: Dark-field illumination, and a graduated mechanical stage. Two exposures are made separately on opposite ends of a 6.5×9 cm. film. Dark-field illumination permits either end of the film to be exposed without affecting the other. The procedure is as follows:

1) A very clean glass slide, free of dust, is selected, and the specimen is placed in position. A freshly prepared "Stay Flat" slide is convenient to use when it is difficult to place the specimen in position.

2) The slide is placed on the graduated mechanical stage and held by the slide holder.

3) The specimen is illuminated as evenly as possible, making sure that it remains under the same lighting conditions at both the extreme left and the extreme right position in the field of view.

4) The slide is moved slowly to one side until its image on the ground glass reaches the end of the field of view without being cut off. The reading on the mechanical stage corresponding to this point is recorded.

5) The slide is moved in the opposite direction to a position corresponding to the previous one, and the reading on the stage is again recorded. Operations 4 and 5 should be repeated several times, until the operator is sure that he can place the specimen in these two positions by reference to the graduated scale of the stage alone.

6) The exposure is calculated, the ground glass is replaced by the film carrier, and two exposures of exactly the same duration are made, one at each predetermined setting of the mechanical stage scale. Another, perhaps simpler, procedure is to replace the film carrier by the ground glass after the first exposure is made, in order to make sure of the position of the second image before the second exposure is made.

7) The prints obtained from such negatives will show two nearly identical images, which must be separated. In the final mounting with rubber cement on white cardboard, reverse the positions of the photographs, placing on the left the one that was originally on the right, and vice versa.

The distance between the two photographs of a stereo-pair is not critical, and can be determined when they are viewed with an adjustable stereoscope. The lenses of most portable stereoscopes can be adjusted to individual interpupillary distances, with no necessity for manipulating each photograph separately. The Abrams Instrument Company of Lansing, Michigan, makes adjustable hand stereoscopes, models CF-8 and B-3, both of which are highly recommended because of their simplicity, efficiency and low cost.

PRACTICABILITY OF THE METHOD

None of the techniques described in this paper requires the development of new skills. Most micropaleontologists are sufficiently adept at handling small fossils to produce a number of satisfactory negatives in a day, after a routine has been established. It may seem slow and tedious to take the specimen off its slide, set in in position again, photograph it, and then put it back in its permanent place. With the aid of the "Stay Flat" slide and a well established routine, however, the technique is fast and efficient. In our laboratory, we produce, on an average, seventy-five negatives on 35 mm. film in a day.

The following routine is suggested for handling specimens:

1) Pull the cover slip of the storage slide partly out, place the slide on the binocular microscope, and wet the specimen.

2) Place pieces of 2- by 3-inch blotting paper on both sides of the microscope. Pick up the wet specimen with the brush and take the slide off the stage. With the left hand, slide a piece of blotting paper into the field of view and place the wet specimen on it, quickly washing off any residual glue with a drop of water.

3) Touch the piece of blotting paper with the brush to draw out excess water, and pick up the specimen again. It will adhere to the brush readily.

4) With the left hand, replace the blotter by the "Stay Flat" slide, and just touch its surface with the specimen. Replace the brush by a fine steel needle and use the latter to orient the specimen. If glycerine is required, dip the needle in the glycerine and place a good-sized drop on the specimen. Spread the liquid around the specimen with the brush, and remove all air bubbles. Use the blotter on the right side to clean the brush and needle. If brown ink is to be applied instead of glycerine, this is the proper time to do so.

5) Place the slide on the photographic microscope for exposure.

6) Place the slide back on the binocular microscope. Remove the specimen from the "Stay Flat" side with a wet brush, and place it on the blotting paper on the left. Glycerine or brown ink can be washed off quickly with one or two drops of water. Then the specimen is picked up, the blotter is pulled out and replaced by the storage slide, and the specimen is set in its original place.

Routines for the other operations should be established in accordance with existing needs. Speed and efficiency depend very much upon simplification of procedures.

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EXPLANATION OF PLATES

PLATE 1

1, 2 *Pseudogaudryina* sp. × 30
These figures demonstrate the use of the pinhole diaphragm. In figure 1, no diaphragm was used with the 10×, 16-mm. achromatic objective. Notice the focal depth, a very thin micrometric plane. In figure 2, the same objective was used equipped with a 575-micron pinhole diaphragm. The increase in depth of field, with a negligible loss of resolution, is remarkable.

3 *Nonion* sp. × 300
This is a contact print of a juvenile *Nonion* magnified 300 times. The photograph was taken with an achromatic 24×, 75-mm. objective and a 200-micron pinhole diaphragm. Exposure time with Panatomic X film was about 5 seconds. Notice the acceptable degree of resolution.

4, 5 *Planulina* sp. × 30
These figures illustrate the use of the "brown ink technique."

6 *Operculinoides* sp. × 20

7, 8 *Streblus* sp. × 200
These figures illustrate the use of blue light with high magnification. Figure 7 was taken with white light, whereas blue light was employed in figure 8. Notice the increase in resolution in figure 8.

9 Radiolarian. × 200

10–12 *Streblus* sp. × 60
These figures show the elimination of glare from shiny surfaces by the use of polarized light. In figure 10, no polarized light was used. In figure 11, two polarized beams were employed. In figure 12, an analyzer was added.

PLATE 2

1, 2 *Globorotalia* sp. × 50
These figures demonstrate the use of the "glycerine technique" to show diagnostic details covered by thin layers of calcite. Figure 1 is a photograph of a dry specimen. In figure 2, the same specimen was photographed under glycerine.

3 *Pseudoglandulina* sp. × 40
This figure shows the high resolving power of the 10× objective equipped with a 575-micron pinhole diaphragm.

4 *Nonion* sp. × 45

5, 6 *Vaginulinopsis* sp. × 30
Another example of the use of the "glycerine technique." Figure 6 was taken with the specimen under glycerine. Note how clearly the partial marcasite replacement is seen in figure 6.

7 *Cibicides* sp. × 100
This figure shows the high resolving power of the 10× objective equipped with a 575-micron pinhole diaphragm.

8 *Peneroplis* sp. × 50
Photographed under glycerine.

9 *Robulus* sp. × 20
Photographed under glycerine. Note the partial marcasite replacement.

10 *Archaias* sp. × 25
Photographed under glycerine.

11 *Elphidium* sp. × 50
Photographed under glycerine with a 10× objective equipped with a 575-micron pinhole diaphragm.

12 *Frondicularia* sp. × 25
Photographed under glycerine.

13 *Vaughanina* sp. × 15

PLATE 3

The photographs on this plate show the great depth of field obtainable with an ordinary microscope objective equipped with a pinhole diaphragm. Photographs of foraminifera in the lateral position, as in figures 1, 2, 4, and 5, are almost impossible to obtain with the lenses available to the average worker. In these figures, the 10× achromatic objective and the 575-micron pinhole diaphragm were employed. In no case was the exposure more than 3 seconds with Panatomic X film, although the total lamp output was less than 250 watts.

1, 4-5, *Robulus* spp.: 1, × 40; 4-5, × 50. 2, 8, *Lagena* spp., × 40. 3, *Miliammina* sp., × 75. 6-7, *Frondicularia* spp., × 60. 9-10, *Spiroloculina* spp.: 9, × 75; 10, × 50. 11, *Pleurostomella* sp., × 60. 12, *Siphonodosaria* sp., × 40.

PLATE 4

The figures assembled on this plate show a variety of textures. All the photographs were taken in a dry medium except figure 5, which was taken under glycerine. True representation of texture is possible if adequate illumination is employed in each case. Figures 2, 7, 8, 9, and 10 were taken with a 3.5× objective and a 1425-micron pinhole diaphragm.

1, *Ammobaculites* sp. × 60. 2, *Gyroidinoides* sp., × 50. 3, 6, Discorbis spp., × 50. 4, *Textularia* sp., × 50. 5, *Lagena* sp., × 60, photographed under glycerine. 7, *Massilina* sp., × 50. 8-9, otoliths, × 30. 10, *Cibicides* sp., × 40. 11, *Nodosaria* sp., × 50. 12, *Robulus* sp., × 40.

PLATE 5

All figures on this plate are stereo-pairs. Contrary to what is commonly believed, the distance between two stereoscopic views is not critical or fixed. The adjustment of the stereoscope and the capacity of adjustment of the eye will permit normal stereoscopic vision when the separation between the two images varies between one and two inches.

1-2, 7, *Globigerina* spp.: 1-2, × 35; 7, × 75. 3, radiolarian, × 75. 4, *Globorotalia* sp., × 40. 5, *Robulus* sp., × 30. 6, ostracode, × 50. 8, *Saracenaria* sp., × 35.

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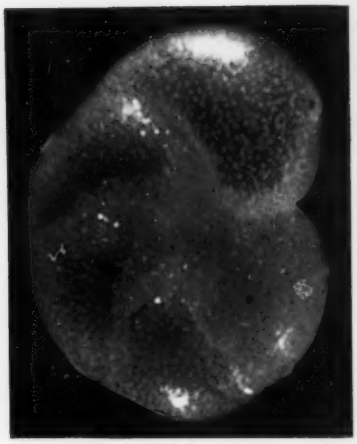

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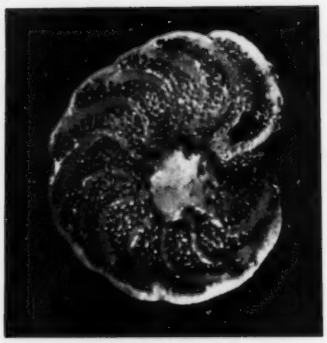

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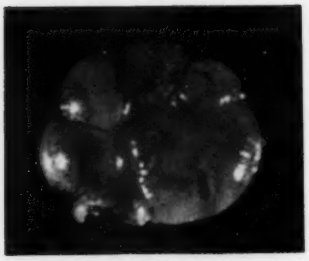

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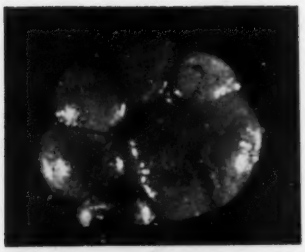

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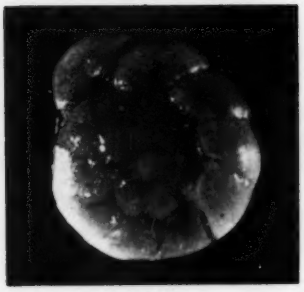

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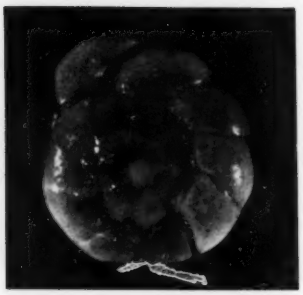

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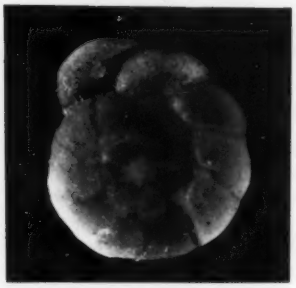

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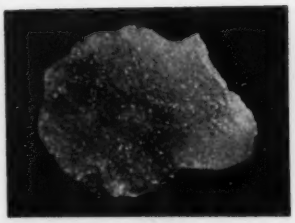

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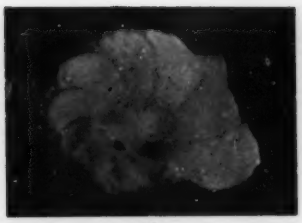

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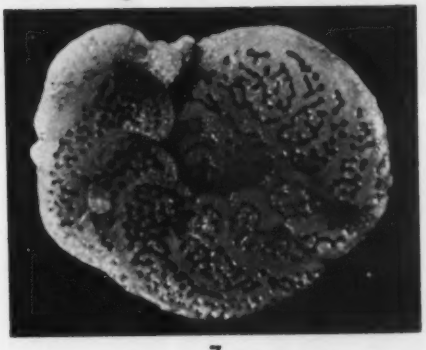

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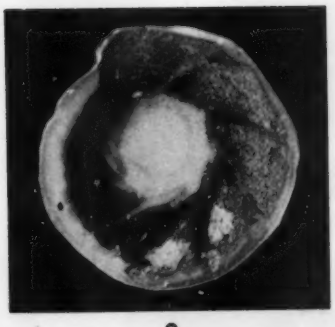

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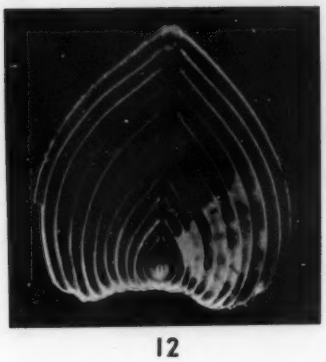

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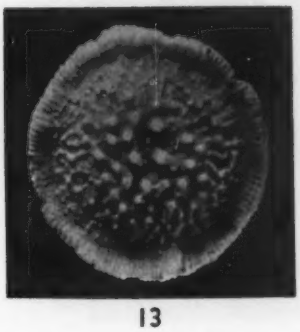

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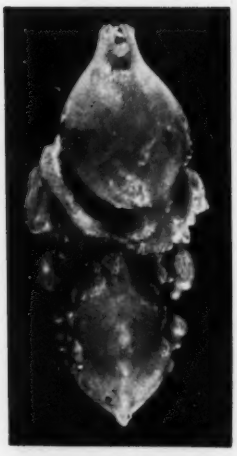
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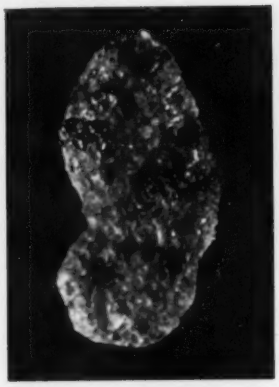

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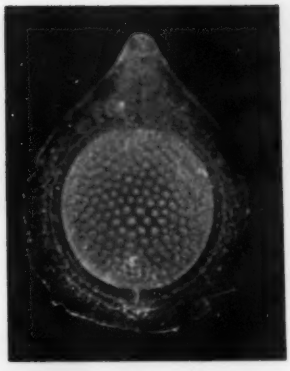

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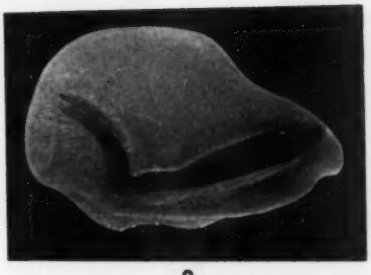

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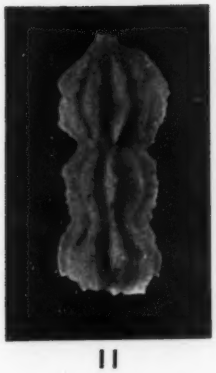

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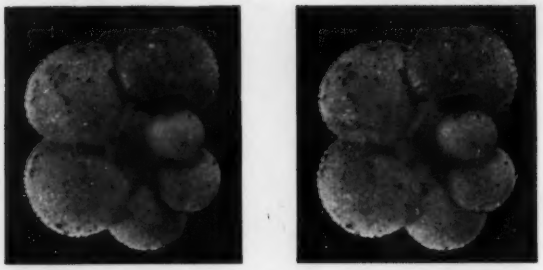

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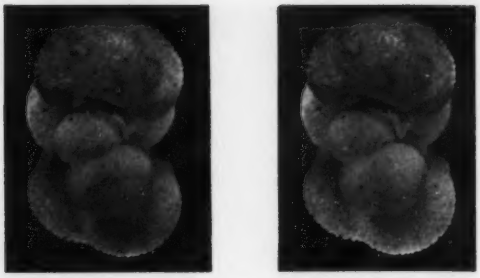

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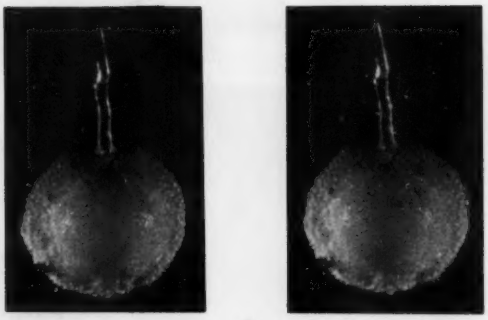

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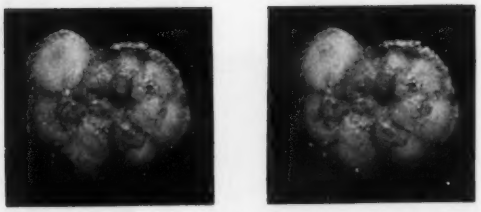

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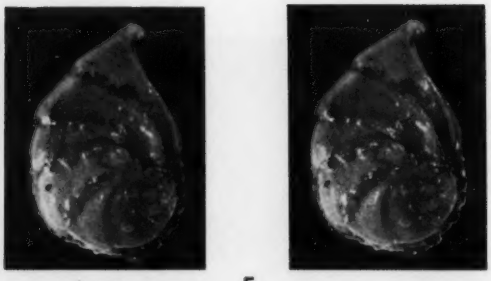

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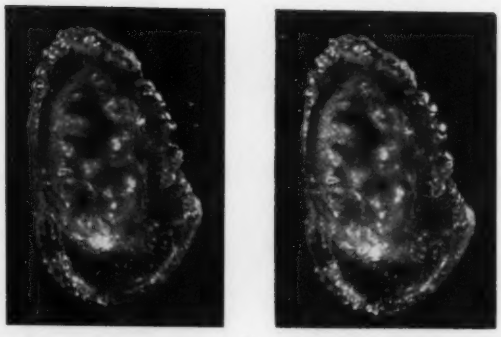

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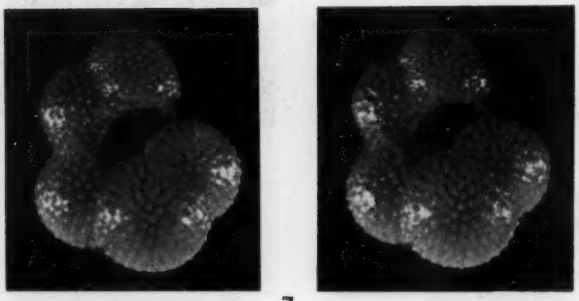

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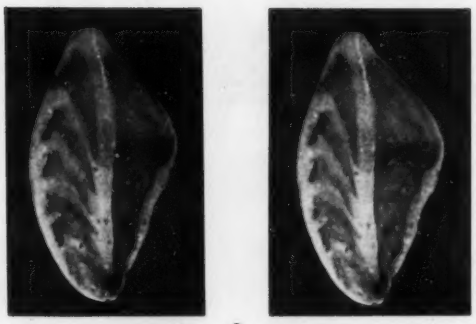

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ABSTRACT: *This paper traces in detail the evolution of the genus* Orbulina *d'Orbigny from a species of* Globigerinoides *similar to* Globigerinoides triloba. *Two independent lines of evolution are discussed, the first leading to* Orbulina universa, *and the second to* "Orbulina" bilobata. *The latter species is removed to a new genus,* Biorbulina, *and two new species of* Globigerinoides *are proposed. The stratigraphic range of* Orbulina *in Trinidad and in Falcón, Venezuela, is discussed, and a preliminary correlation of the Oligo-Miocene sediments of the two areas is given.*

Origin and evolution of the foraminiferal genus Orbulina d'Orbigny

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INTRODUCTION

The origin of the genus *Orbulina* has been the subject of much speculation since its first description by d'Orbigny in 1839. Although various authors have postulated a globigerine forerunner from a study of the ontogeny of the genus (Brady, 1884; Cushman and Dorsey, 1940; Bronnimann, 1951), no direct links with a possible ancestor have actually been observed. These links are now discussed on the basis of material collected by R. Muhlemann from a closely sampled section near Pozón, District of Acosta, eastern Falcón, Venezuela.

In twelve consecutive samples from this section there is a concurrence of *Orbulina*-like forms with *Globigerinatella insueta*. When the forms in each sample are arranged, they make a series of completely gradational sequences beginning with a form similar to the figured type of *Globigerinoides triloba* (Reuss) and extending via *Globigerinoides bispherica* Todd to specimens in which the last chamber almost entirely envelops the earlier part of the test (text-figs. 1-3). In the uppermost four samples, specimens of *Orbulina suturalis* were found, and in the last two samples *Orbulina universa* was present.

The forms between *Globigerinoides bispherica* Todd and *Orbulina suturalis* Bronnimann are transitional; the degree to which the last chamber envelops the earlier portion of the test varies from about 40 per cent to types where the initial portion is only just visible, while the apertures become numerous short slits but retain characters reminiscent of some types of *Globigerinoides*. Certain other types show a transition from small, discontinuous slit-like apertures to the adoption of rounded pore-like apertures similar to those observed in *Orbulina suturalis* Bronnimann. Other characters, such as wall structure, arrangement of chambers, and pore size and density, also show gradual transition.

In addition to the evolutionary sequence leading from a form similar to *Globigerinoides triloba* via *Globigerinoides bispherica* to *Orbulina universa*, a further sequence leading from *Globigerinoides bispherica* to *Biorbulina [Orbulina] bilobata* has also been observed in the same samples (text-fig. 3).

The holotypes of the species and subspecies described in this paper are deposited at the U. S. National Museum (Cushman Collection), Washington, D. C. A slide showing the complete sequences has been sent to the U. S. National Museum. Paratypes will be sent to the Museum of Natural History, Basel, Switzerland, and to the British Museum (Natural History), London.

STAGES IN THE EVOLUTION OF ORBULINA UNIVERSA

The continuity of the evolutionary sequences is complete and unbroken, but certain forms can be grouped around central types that can be used to designate stages of evolution (text-fig. 3). These stages are outlined below, with only the salient features noted; the detailed morphology is given in full in the section on systematics.

Stage 1: Globigerinoides triloba (Reuss)

Text-figure 1, numbers 1-3

This stage is represented by a central form similar to the figured type of *Globigerinoides triloba* described by Reuss in 1850. Externally the form shows a rather indistinct trochoid initial portion of about six chambers, which increase fairly regularly and slowly. The initial portion is followed by three chambers that abruptly become inflated. The last chamber, which covers the umbilicus, envelops about 10 per cent of the early part of the test. When the last chamber is removed, an open trochoid spire consisting of three and one-half to four chambers in the last whorl is observed. The ventral apertures of the penultimate and earlier chambers are large semicircular openings with well-formed, raised crescentic lips.

Stage 2: Globigerinoides bispherica Todd

Text-figure 1, numbers 4-7; text-figure 2, numbers 10-11

The central type of this stage is similar to the figured holotype of Todd's species described from Saipan. The last chamber embraces about 30 per cent of the earlier part of the test, giving a general ovoid shape. The apertures of the last chamber show a tendency to become elongate slits with occasional constrictions of clear shell material, which tend to subdivide them. When the last chamber is removed, an open spire of ten to twelve vitreous, semiglobular chambers is seen, with four chambers in the last whorl, each chamber having a large semicircular aperture with a well developed crescentic lip.

Stage 3: Globigerinoides glomerosa curva Blow

Text-figure 1, numbers 9-14

The salient features of this stage are: (1) The last chamber covers the umbilicus and embraces between 40 and 70 per cent of the earlier test; (2) the apertures of the last chamber are variable in number, ranging from four to eight; (3) the earlier part of the test previous to the last chamber consists of ten to twelve chambers arranged in an open trochoid spire with three to four chambers in the last whorl. These early chambers are semiglobular, vitreous, and rather fragile, and have large semicircular ventral apertures.

Stage 4: Globigerinoides glomerosa glomerosa Blow

Text-figure 1, numbers 15-19; text-figure 2, numbers 1-2

The most important feature of this stage is that the apertures of the last and the earlier chambers are short discrete slits and not rounded openings. The last chamber embraces more than 75 per cent of the earlier part of the test.

Stage 5: Globigerinoides glomerosa circularis Blow

Text-figure 2, numbers 3-4

In this stage the apertures become subcircular to circular pore-like openings, which are confined to the sutures.

Stage 6: Orbulina suturalis Bronnimann

Text-figure 2, numbers 5-7

The central type of this stage is similar to the figured holotype of *Orbulina suturalis* described by Bronnimann (1951, p. 135), and has circular or subcircular apertural pores along the suture between the last and the penultimate chamber; it also has apertural pores distributed irregularly over the area of the last chamber.

Stage 7: Orbulina universa d'Orbigny

Text-figure 2, numbers 8-9

No trace of the early part of the test is visible from the exterior, but, in all specimens investigated by the writer, the early chambers are present inside the last chamber. *Orbulina universa* often has circular or subcircular openings distributed irregularly over the area of the last chamber, but in advanced forms the numerous minute perforations appear to take over the function of apertures.

STAGES IN THE EVOLUTION OF BIORBULINA BILOBATA

Stage A: Globigerinoides bispherica Todd

Text-figure 1, numbers 4-7; text-figure 2, numbers 10-11

This form has been discussed previously. A trend toward the reduction in relative size of the chambers previous to the penultimate can be noticed first in some variants of this species. A number of forms transitional to Stage B occur; two such forms are illustrated (text-fig. 2, nos. 10-11).

Stage B: Globigerinoides transitoria Blow

Text-figure 2, numbers 12-15

The following points are emphasized: (1) The penultimate chamber embraces the earlier chambers from 40 to 60 per cent; (2) the apertures are slit-like or rectangular openings, and are situated in the sutures between the last, the penultimate and the earlier chambers.

Stage C: Biorbulina bilobata (d'Orbigny)

Text-figure 2, number 16

The apertures of this form are reduced to a system of apertural pores, some or all of which are distributed irregularly over the area of the penultimate and last chambers. In more primitive forms, there is a tendency for the apertures to be concentrated over the penultimate chamber and in the suture between the last and the penultimate chamber.

THE EVOLUTION OF ORBULINA AND BIORBULINA

The stages outlined above (Stages 1-7 and Stages A-C) indicate that *Orbulina universa* and *Biorbulina bilobata* are derived from *Globigerinoides triloba* (Reuss). *Globigerinoides triloba* is itself a member of a closely related group that includes *Globigerinoides sacculifera*. This group first appears in the *Globigerina dissimilis* zone in Trinidad and in the *"Uvigerinella" sparsicostata* zone in eastern Falcón, Venezuela (Renz, 1948).

Observations concerning the distribution of supplementary apertures in *Globigerinoides triloba* (Reuss) and *Globigerinoides sacculifera* (Brady) show that supplementary apertures are frequently restricted to the penultimate and last chamber, and are absent in the earlier ones. Accordingly, *Globigerinoides* may be regarded as having a *Globigerina* stage in its ontogeny. In *Globigerinoides glomerosa glomerosa*, the apertures of the last chamber are numerous short slits, but every transition is present between the slit-like apertures and the subcircular or circular pore-like apertures of *Globigerinoides glomerosa circularis*. The nature of the pore-like apertures of this form is in no way different from the nature of the pore-like apertures of *Orbulina suturalis*. However, in *Orbulina suturalis* the apertures show successive migration from the sutural positions, becoming distributed over the area of the last chamber. The writer regards this as indicating the gradual exclusion of the ontogenic *Globigerinoides* stage in the evolution of *Orbulina suturalis*, culminating in the total exclusion of this stage in *Orbulina universa*.

Although the internal arrangement of chambers and external morphology show gradual transitions from Stage 1 to Stage 7, the same fundamental structural pattern is present in all stages. This fundamental structure consists of: (1) The umbilical position of the last chamber; (2) the similarity of the large semicircular apertures in the earlier chambers; (3) the arrangement of the chambers previous to the last.

The main trends in the development of *Orbulina suturalis* and *Orbulina universa* are:

a) Gradual envelopment of the earlier part of the test by the last chamber.

b) Subdivision and gradual increase in the number of supplementary apertures in *Globigerinoides triloba* and *Globigerinoides bispherica*, leading to the discontinuous slit-like apertural system in *Globigerinoides glomerosa glomerosa*, the slits eventually becoming oval or rounded pores, as seen in *Globigerinoides glomerosa circularis*. Later, the apertural pores migrate from the sutural positions, becoming irregularly distributed over the area of the last chamber, as in *Orbulina suturalis* and *Orbulina universa*.

c) A general reduction in the size of the perforations over the surface of the test. However, the size and density of these perforations varies in the ontogeny of some specimens, especially those belonging to Stages 3, 4 and 5; thus, in *Globigerinoides glomerosa* the size and density of the perforations is similar to that of *Orbulina suturalis* over the last chamber, but over the earlier chambers it is like that of *Globigerinoides bispherica*.

The later evolution of *Orbulina suturalis* is variable. Forms in which the protuberance of the early chambers is considerable often occur in younger horizons than forms in which the early part is small (Bronnimann, 1951, text-figs. 2, 3 and 4). The important biocharacter does not seem to be the degree of protuberance of the early part of the test, but whether or not the apertural pores are areally distributed or retained in the sutural positions. Variations in the size of the chambers within the enveloping last chamber are also irregular, but an overall trend toward reduction in size may be present in material investigated between the *Globorotalia fohsi barisanensis* subzone and the *Globorotalia menardii* zone in both Trinidad and Venezuela.

Orbulina universa shows a distinct trend toward reduction in size with a concomitant increase in fragility of the early chambers. There is also a series of specimens in which the apertural pores are found successively farther away from the dorsal pole of the test.

The phylogeny of *Biorbulina bilobata* is by comparable stages, and the trends described above are broadly recognisable except that it is the penultimate chamber which embraces the earlier chambers. The later evolution of *Biorbulina bilobata* shows the migration of apertural pores away from the sutural positions to all parts of the test. The amount to which the penultimate

chamber embraces the earlier chambers is variable; forms in which the earlier chambers protrude above the general contour of the test often coexist with forms in which no external indications of the early chambers are seen.

In the writer's opinion, *Orbulina suturalis* Bronnimann and *Biorbulina bilobata* (d'Orbigny) were derived from a common ancestor, i.e., *Globigerinoides bispherica* Todd, for the following reasons:

a) The morphological differences discussed previously are apparent from the inception of the evolutionary sequences.

b) The sequences, once initiated, are distinct one from the other and proceed at different rates, so that *Biorbulina bilobata* appears before either *Orbulina suturalis* or *Orbulina universa*.

Accordingly, the following two bioseries are proposed (text-fig. 3):

Bioseries I

Globigerinoides triloba → *Globigerinoides bispherica* → *Globigerinoides glomerosa* → *Orbulina suturalis* → *Orbulina universa*.

Characterised by the tendency of the last chamber to completely envelop all the earlier ones, while the apertures increase in number but decrease in size. In later stages the apertures migrate from the sutural positions and become distributed over the area of the last chamber.

Bioseries II

Globigerinoides triloba → *Globigerinoides bispherica* → *Globigerinoides transitoria* → *Biorbulina bilobata*.

Characterised by the tendency of the penultimate chamber to embrace the earlier ones and of the ultimate and penultimate chambers to become equal in size; also by an increase in the number of apertures which become pore-like, these in turn migrating from the sutural positions.

If the last chamber of *Biorbulina bilobata* is removed, the form appears similar to either *Orbulina suturalis* or *Orbulina universa*. Consequently, the writer recognises the possibility that some late forms of *Orbulina* and *Biorbulina* may be polyphyletic. This possible relationship is indicated by the horizontal arrows between *Orbulina suturalis, Orbulina universa* and *Biorbulina bilobata* in text-figure 3.

TAXONOMIC PROBLEMS

The evolutionary sequences leading from *Globigerinoides triloba* to *Orbulina universa* and *Biorbulina bilobata* bring to light some of the inadequacies of the present nomenclatural system. It is difficult to decide upon the limits which will satisfactorily define the taxonomic position of the forms involved, since the various biocharacters do not evolve at the same rate. It is especially difficult to consider where in the evolutionary sequence the boundary should be placed between *Globigerinoides* and *Orbulina*. A feature of *Globigerinoides* is the possession of multiple apertures lying in the sutural positions. The actual shape and number of the apertures does not, at present, seem to be of great significance. It is considered that a valid distinction between *Globigerinoides* and *Orbulina* can be made by referring all forms in which the apertures are sutural in position, regardless of shape, to *Globigerinoides*, and those in which some or all of the apertures are areally distributed to *Orbulina*. Accordingly, Stages 4 and 5, in which the apertures are sutural, are referred to the genus *Globigerinoides*. It is realised that this splits into two genera forms which are otherwise united by characters such as wall structure and general overall shape of the test, and that the decision to refer Stages 4 and 5 to *Globigerinoides* is not entirely satisfactory.

The boundary between *Orbulina suturalis* and *Orbulina universa* is also difficult to place, but it is considered that it is best put where the last trace of the earlier chambers has disappeared and when none of the apertures lies in the sutural position.

It is considered that the forms previously referred to *Orbulina bilobata* (d'Orbigny) have evolved independently from *Globigerinoides bispherica*, and that the essential morphological difference from *Orbulina suturalis* and *Orbulina universa* is that in *Orbulina bilobata* the penultimate chamber embraces the earlier ones, not the ultimate chamber as in those species of *Orbulina*. Because of this fact, it is considered that a new genus is warranted for *Orbulina bilobata*. *Orbulina bilobata* is therefore removed to a new genus, *Biorbulina*.

The distinction between *Globigerinoides* and *Biorbulina* is made on the basis of the same principle discussed previously, i.e., forms in which the apertures are retained in the sutures are referred to the genus *Globigerinoides*, while those in which some or all of the apertures are distributed over the area of the penultimate or ultimate chamber are referred to the genus *Biorbulina*.

The diagnosis of *Biorbulina* and an emendation of d'Orbigny's description of *Orbulina* are given in the section on systematics.

STRATIGRAPHIC DISTRIBUTION OF ORBULINA

The sudden appearance of rich *Orbulina*-bearing assemblages in Middle Tertiary sediments of widely separated localities such as Sumatra (LeRoy, 1948, 1952), the Caribbean (Cushman, 1945; Bronnimann, 1951), and Egypt (Tromp, 1949) is well known. This study shows that the evolution of *Orbulina* from *Globigerinoides bispherica* took place during a short time interval corresponding to the upper part of the *Globigerinatella insueta* zone in Trinidad, Venezuela, and Barbados, and that the genus rapidly became abundant.

The range of *Orbulina universa* is given by Tromp (1949) and by LeRoy (1948) as Middle Tertiary to Recent. Glaessner (1945) states that most pre-Miocene records of *Orbulina* d'Orbigny are in error. Bowen (1955) discusses the generic position of a number of specimens referred previously to the genus *Orbulina* d'Orbigny. He comes to the conclusion that many of these forms are not *Orbulina*, and that pre-Oligocene and possibly pre-Miocene records of the genus are incorrect.

The writer is at present engaged in a detailed study of the planktonic foraminifera of the Oligo-Miocene of eastern Falcón, Venezuela (Agua Salada group). Preliminary results indicate that it is possible to recognize the biozones erected by Bolli (1951) on the basis of the planktonic foraminifera of the Oligo-Miocene Cipero and Lengua formations of Trinidad. A preliminary correlation between these biozones and those erected by Renz (1948) on the basis of the benthonic foraminifera of the Agua Salada group is shown in text-figure 4. This correlation makes it possible to compare the ranges of *Orbulina* in Trinidad and in Venezuela.

Trinidad

Cushman and Stainforth (1945) recorded the first occurrence of *Orbulina universa* in the *Globorotalia fohsi* zone of the Oligo-Miocene Cipero formation of Trinidad. The subdivision of this zone by Bolli (1951) into four subzones enabled Bronnimann (1951, p. 131) to show that, in the Cipero formation, *Orbulina suturalis* appears in the *Globorotalia fohsi barisanensis* subzone, whereas *Orbulina bilobata* and *Orbulina universa* occur first in the higher *Globorotalia fohsi fohsi* subzone and *Globorotalia fohsi lobata* subzone, respectively.

Recent investigations reveal that a number of samples from the *Globigerinatella insueta* zone of the Cipero and Brasso formations show evolutionary stages of both *Orbulina universa* and *Biorbulina bilobata*, although no continuous section records the complete evolution.

The type locality of the *Globigerinatella insueta* zone of the Cipero formation (Cipero Coast, south of San Fernando, H.R. locality 108, T.L.L. Cat. No. 21734) contains *Globigerinoides bispherica* and *Globigerinoides transitoria*. The Ste. Croix Quarry type locality (R.M. locality 14873, T.L.L. Cat. No. 7266) contains the same fauna, and Rutsch (1934) considered that the pteropods of this locality show clear relationship to those of the Burdigalian and Helvetian of northern Italy.

A number of samples from the *Globigerinatella insueta* zone of the Brasso formation show all the stages of both the *Orbulina universa* and *Biorbulina bilobata* sequences. At the type locality of the *Globigerinatella insueta* zone of the Brasso formation (K.R. locality 11637, T.L.L. Cat. No. 74191), formerly known as the Esmeralda member (Suter, 1951), Miocene pteropods occur (Rutsch, 1934) together with *Globigerinoides glomerosa. Orbulina suturalis, Globigerinoides bispherica, Globigerinoides transitoria,* and *Biorbulina bilobata.*

This occurrence of Miocene (Burdigalian) megafossils in the *Globigerinatella insueta* zone of both the Cipero and the Brasso formations suggests that at least part of this zone should be regarded as Lower Miocene. *Orbulina* originates in the uppermost part of the same zone.

Venezuela (eastern Falcón)

The evolution of *Orbulina suturalis, Orbulina universa* and *Biorbulina bilobata* from *Globigerinoides triloba* was first observed in a series of surface samples collected by R. Muhlemann in the Pozón area, eastern Falcón. Later reference to the subsurface section in Pozón well No. 3 in the same area also showed sequences identical to those seen in the surface samples. In Pozón well No. 3, which was very nearly completely cored, the evolutionary sequence occurs just above the Policarpio greensand member of the Pozón formation (1063-1169 feet). This interval lies in the middle part of the *Siphogenerina transversa* zone (Renz, 1948). *Globigerinoides bispherica* first appears in the lower part of the same zone. Renz (1948, pp. 34 and 149) reported *Orbulina* from the *"Uvigerinella" sparsicostata* zone (San Lorenzo formation), but

further investigations of core and surface samples have not substantiated this record. The genus *Orbulina* first appears above the Policarpio greensand member at the base of the Pozón formation.

Barbados

Samples from the Bissex Hill formation collected by J. P. Beckmann in the Consets region show the concurrence of *Globigerinatella insueta, Globigerinoides bispherica, Globigerinoides transitoria, Biorbulina bilobata, Globigerinoides glomerosa* and *Orbulina suturalis.*

Saipan

The writer has been in communication with Miss Ruth Todd (U. S. Geological Survey) and sent her a series of specimens illustrating the evolutionary sequences previously discussed. In her reply of August 9, 1955, she wrote: "After looking at your slide that illustrates the evolutionary sequence from *Globigerinoides triloba* (Reuss) → *Globigerinoides bispherica* Todd → *Globigerinoides glomerosa* Blow → *Orbulina suturalis* Bronnimann → *Orbulina universa* d'Orbigny, I mounted a similar series, but with the difference that my specimens all come from a single sample: C-85, the Saipan sample from which *G. bispherica* and *G. subquadrata* were described." Todd (1954, p. 674) mentions the occurrence of *Globigerinatella insueta* in the Saipan sample, and since the concurrence of *Orbulina, Globigerinoides glomerosa* and *Globigerinatella insueta* is strictly limited (text-fig. 4), it is reasonable to propose a correlation between the horizons represented by samples no. C-85 (Saipan) and no. R.M. 19285 (Falcón, Venezuela).

SYSTEMATIC DESCRIPTIONS

Phylum PROTOZOA

Order FORAMINIFERA

Family GLOBIGERINIDAE

Subfamily GLOBIGERININAE

Genus GLOBIGERINOIDES Cushman, 1927

Globigerinoides triloba (Reuss)
Text-figure 1, nos. 1-3

Globigerina triloba REUSS, 1850, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Denkschr., vol. 1, p. 374, pl. 47, fig. 11.

Remarks: Reuss mentions, in his type description, the supplementary aperture present in the last chamber, and, accordingly, this species is referred to the genus *Globigerinoides.* When the last chamber is removed, an open spire of ten to twelve chambers, with four chambers in the last whorl, is seen. The ventral faces of the earlier chambers are vitreous and have very fine pores. These chambers also possess a large semicircular ventral aperture (text-fig. 1, no. 3) with a well-marked crescentic lip. The last chamber covers a rather wide umbilicus. In the early forms of the species, the supplementary apertures are present only in the last and penultimate chambers; in later forms, supplementary apertures appear in early chambers.

Occurrence: This form first appears in the middle part of the *Globigerina dissimilis* zone of the Cipero formation in Trinidad, and in the *"Uvigerinella" sparsicostata* zone of the San Lorenzo formation, eastern Falcón, Venezuela. It persists throughout the Upper Oligocene and Miocene in both Venezuela and Trinidad.

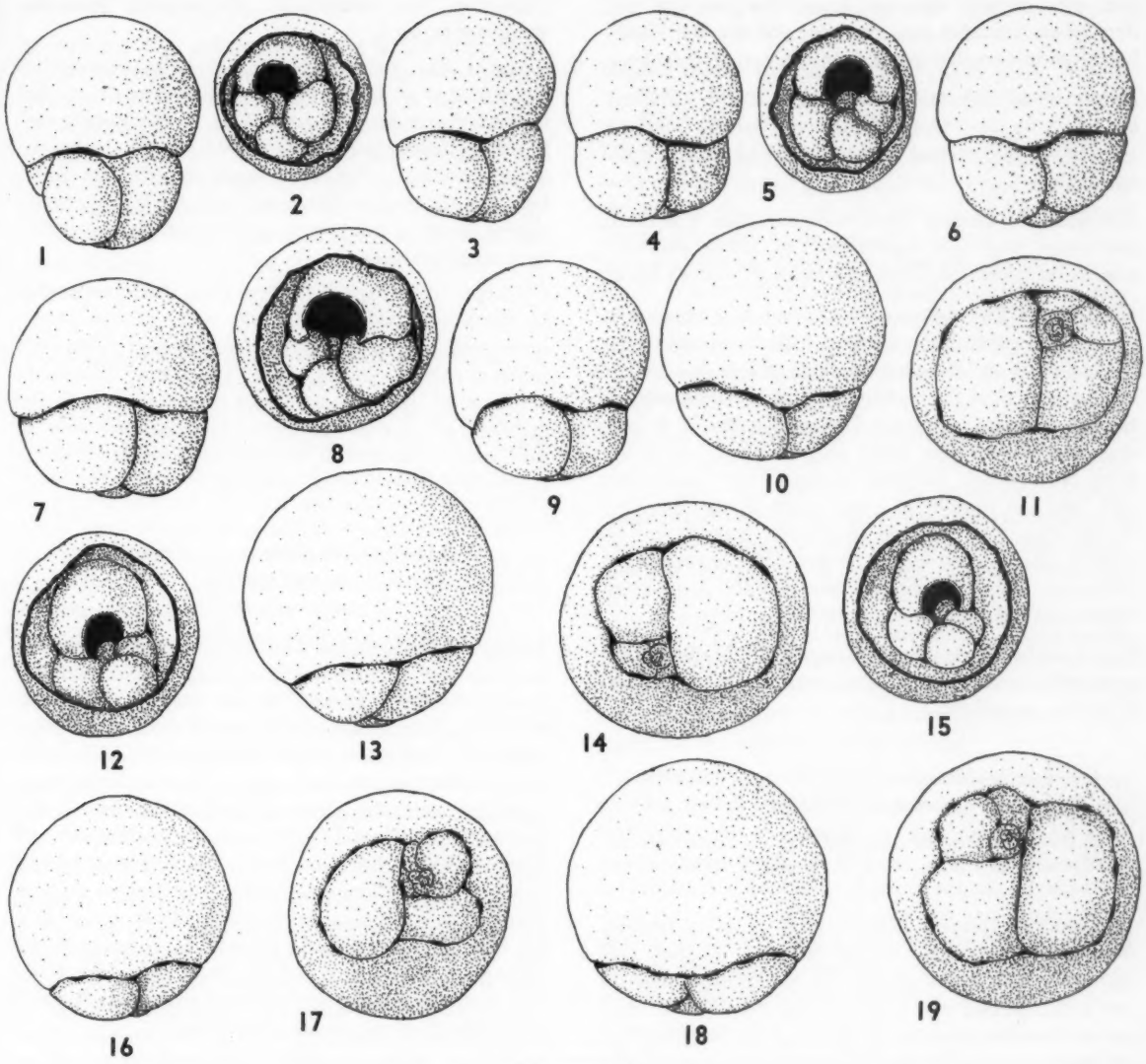
Globigerinoides bispherica Todd, emend. Blow
Text-figure 1, nos. 4-8; text-figure 2, nos. 10-11

Globigerinoides bispherica TODD, 1954, Amer. Jour. Sci., vol. 252, p. 681, pl. 1, fig. 1a-c.

The writer discussed with Miss Ruth Todd the desirability of emending her type description of *Globigerinoides bispherica* so as to exclude the two species *Globigerinoides glomerosa* Blow and *Globigerinoides transitoria* Blow, which were covered to a greater or lesser degree by her original description of *Globigerinoides bispherica* (Todd, 1954).

Emended diagnosis: Test consisting of three chambers in the last whorl, with the last chamber approximately equal in size to the penultimate and third chambers together. The last chamber embraces from 15 to 35 per cent of the penultimate and earlier chambers. The penultimate chamber also embraces from 10 to 30 per cent of the previous chambers. Forms in which the penultimate chamber more strongly embraces the earlier ones do not usually have the last chamber embracing more than about 25 per cent of the earlier test. Sutures distinct and incised. Apertures of the last chamber slit-like, often elongate, two to four in number and situated in the suture between the last and the earlier chambers. Supplementary apertures present in the sutures between the penultimate and the earlier chambers.

The last chamber, which is umbilical in position, covers an open spire of ten to twelve semiglobular, vitreous earlier chambers. Each of the earlier chambers has a large semicircular ventral aperture with a well-formed crescentic lip.



TEXT-FIGURE 1

All from sample R.M. 19285 (T.L.L. Cat No. 130301), occurring with *Globigerinatella insueta* in the *Siphogenerina transversa* zone, Pozón formation, eastern Falcón, Venezuela; all × ca. 60. 1-3, *Globigerinoides triloba* (Reuss): 1, side view of form similar to figured type of species; 2, umbilical view of specimen with last chamber opened to show arrangement of earlier chambers around umbilicus and large semicircular apertures of penultimate chamber; 3, side view of form similar to this species but showing characters transitional to *Globigerinoides bispherica* Todd. 4-8, *Globigerinoides bispherica* Todd: 4, side view; 5, umbilical view of specimen with last chamber opened; 6-8, forms similar to *Globigerinoides bispherica* but showing characters transitional to *Globigerinoides glomerosa curva* Blow, n. subsp.: 6-7, side views; 8, umbilical view of form similar to no. 7, with last chamber opened. 9-14, variants of *Globigerinoides glomerosa curva* Blow, n. subsp.: 9-10, 13, side view of three specimens; 11, 14, spiral views of specimens shown in nos. 10 and 13, respectively (10-11, holotype); 12, umbilical view of specimen with last chamber opened. 15-19, *Globigerinoides glomerosa glomerosa* Blow, n. subsp.: 15, umbilical view of specimen with last chamber opened; 16, 18, side views; 17, 19, spiral views of specimens shown in nos. 16 and 18, respectively (18-19, holotype).

Wall calcareous, perforate, roughly cancellate, and composed of more than one layer. The pore size and density are variable over the test, and the last chamber often has smaller pores than the earlier chambers.

Holotype: Globigerinoides bispherica Todd, 1954, op. cit., pl. 1, fig. la-c; Upper Oligocene, Saipan, Mariana Islands. U. S. National Museum, Washington, D. C., no. 548876.

Remarks: The species shows wide variation, and there are forms that are transitional to *Globigerinoides transitoria* Blow and *Globigerinoides glomerosa* Blow.

Occurrence: The species, as emended, first appears in the middle part of the *Globigerinatella insueta* zone of the Cipero and Brasso formations of Trinidad, and in the lower part of the *Siphogenerina transversa* zone of the San Lorenzo formation, Falcón, Venezuela. It persists into the extreme basal part of the *Globorotalia fohsi barisanensis* subzone in the Cipero formation, and into the middle to upper part of the *Siphogenerina transversa* zone in the Pozón formation. The species also occurs in the Bissex Hill formation of Barbados. Todd originally described the form from Saipan, and states that it occurs in Ecuador.

It is a useful marker for the upper half of the *Globigerinatella insueta* zone of the Cipero formation, where it is often abundant.

Globigerinoides glomerosa Blow, new species
Text-figure 1, nos. 9-19; text-figure 2, nos. 1-4

Orbulina suturalis Bronnimann, 1951 (part), Contr. Cushman Found. Foram. Res., vol. 2, pt. 4, p. 135, text-fig. 2, nos. 3-4, 9, 14.

Diagnosis of species: Test ovoid to nearly spherical, with the last chamber nearly globular, inflated, and embracing the earlier part of the test to more than 40 per cent. Dorsal apertures of the penultimate and earlier chambers and the apertures of the last chamber are short narrow slits or circular openings lying in the sutures but not in the area of the last chamber. Apertures of the last chamber are numerous. The last chamber covers the umbilicus and an open spire of ten to twelve semiglobular, vitreous earlier chambers. The ventral apertures of the penultimate and earlier chambers are large semicircular openings with raised crescentic lips. Wall calcareous, composed of more than one layer, rather coarsely cancellate.

Holotype: Globigerinoides glomerosa glomerosa Blow, n. sp. et n. subsp., text-fig. 2, nos. 18-19; sample no. R.M. 19285, T.L.L. Cat. No. 130301, Pozón formation, *Siphogenerina transversa* zone, auger line near Pozón, eastern Falcón, Venezuela. Deposited in the Cushman Collection (no. 64585), U. S. National Museum, Washington, D. C.

Remarks: This form differs from *Orbulina suturalis* in the retention of apertures in the sutural positions and the fact that it does not have them areally distributed. It differs from *Globigerinoides bispherica* in having more apertures in the suture separating the last chamber from the earlier chambers, and also in the greater degree to which the last chamber embraces the earlier part of the test.

Occurrence: This species ranges from the topmost part of the *Globigerinatella insueta* zone in the Brasso formation into the overlying *Globorotalia fohsi barisanensis* subzone in the Cipero and Brasso formations of Trinidad. In Venezuela, the species occurs in the middle part of the *Siphogenerina transversa* zone in the Pozón formation. It has also been observed in the Bissex Hill formation of Barbados.

Globigerinoides glomerosa curva Blow, new subspecies
Text-figure 1, nos. 9-14

Diagnosis of subspecies: Test ovoid to nearly spherical, with the last chamber semiglobular, inflated, and embracing between 40 and 70 per cent of the earlier test. Dorsal apertures of the penultimate and earlier chambers, and the apertures of the last chamber, are narrow slits lying in the sutures. Four to eight apertures present in the suture of the last chamber. Initial part rather indistinct, but the last, penultimate and third chambers clearly marked by fairly deeply incised sutures. The last chamber, which is umbilical in position, covers an open spire of ten to twelve semiglobular, vitreous earlier chambers with large semicircular apertures. Wall composed of more than one layer; wall texture variable, last chamber often less coarsely cancellate than the earlier chambers.

Holotype: Globigerinoides glomerosa curva Blow, n. subsp., text-fig. 1, nos. 10-11; sample no. R.M. 19285, T.L.L. Cat. No. 130301, Pozón formation, *Siphogenerina transversa* zone, auger line near Pozón, eastern Falcón, Venezuela. Deposited in the Cushman Collection (no. 64587), U. S. National Museum, Washington, D. C.

Remarks: Forms transitional to *Globigerinoides bispherica* occur. This subspecies differs from *Globigerinoides bispherica* in having an almost spherical test and in the more numerous apertures of the last chamber. It seems likely that some of the additional apertures of the last chamber were formed by constriction

of the rather elongate apertures of *Globigerinoides bispherica* Todd (Todd, 1954).

Occurrence: This subspecies occurs in the uppermost part of the *Globigerinatella insueta* zone in the Brasso formation of Trinidad; it also occurs in the middle part of the *Siphogenerina transversa* zone in the Pozón formation of Falcón, Venezuela. It was abundant for a short time, persisted into the basal part of the *Globorotalia fohsi barisanensis* subzone, and then abruptly became extinct. It has also been found in sediments of corresponding age in the Bissex Hill formation of Barbados.

Globigerinoides glomerosa glomerosa Blow, new subspecies
Text-figure 1, nos. 15-19; text-figure 2, nos. 1-2

Diagnosis of subspecies: Test nearly spherical, with last chamber nearly globular, inflated, and embracing the earlier part of the test more than 75 per cent. Dorsal apertures of the penultimate and earlier chambers, and the apertures of the last chamber, are numerous short narrow slits confined to sutures between the last, penultimate and earlier chambers. Apertures of the last chamber more than eight. Sutures fairly deeply incised.

Holotype: Globigerinoides glomerosa glomerosa Blow, n. subsp., text-fig. 2, nos. 18-19; sample no. R.M. 19285, T.L.L. Cat. No. 130301, Pozón formation, *Siphogenerina transversa* zone, auger line near Pozón, eastern Falcón, Venezuela. Deposited in the Cushman Collection (no. 64585), U. S. National Museum, Washington, D. C.

Remarks: The subspecies is defined by the possession of discrete short slits rather than subcircular or circular apertural pores. The slits are confined to the sutural positions and are not distributed over the area of the last chamber. The sutures are rather more deeply incised than in *Globigerinoides glomerosa circularis*. It differs from *Globigerinoides glomerosa curva* in having more apertures in the suture between the last and earlier chambers and in having the last chamber embracing the earlier part of the test to a greater degree.

Occurrence: The subspecies has a short range in the uppermost part of the *Globigerinatella insueta* zone in the Brasso formation, and extends into the extreme basal part of the overlying *Globorotalia fohsi barisanensis* subzone in the Cipero and Brasso formations in Trinidad. In Venezuela, it occurs in the middle part of the *Siphogenerina transversa* zone in the Pozón formation of Falcón.

Globigerinoides glomerosa circularis Blow, new subspecies
Text-figure 2, nos. 3-4

Orbulina suturalis Bronnimann, 1951 (part), Contr. Cushman Found. Foram. Res., vol. 2, pt. 4, p. 135, text-fig. 2, nos. 3-4, 9, 14.

Diagnosis of subspecies: Test nearly spherical, with last chamber almost globular, inflated, and embracing the earlier part of the test more than 75 per cent. Dorsal apertures of the penultimate and earlier chambers, and the apertures of the last chamber, are circular or subcircular pore-like openings. Apertures situated in the sutures between the last, penultimate and earlier chamber and not in the area of the last chamber. Sutures less deeply incised than in *Globigerinoides glomerosa glomerosa.*

Holotype: Globigerinoides glomerosa circularis Blow, n. subsp., text-fig. 2, nos. 3-4; sample no. R.M. 19285, T.L.L. Cat. No. 130301, Pozón formation, *Siphogenerina transversa* zone, auger line near Pozón, eastern Falcón, Venezuela. Deposited in the Cushman Collection (no. 64589), U. S. National Museum, Washington, D. C.

Remarks: This subspecies differs from *Globigerinoides glomerosa glomerosa* in not having discrete, short slit-like apertures, but possessing rounded pore-like apertures. It differs from *Orbulina suturalis* in that all the apertures are confined to the sutures.

Occurrence: The subspecies ranges from the topmost part of *Globigerinatella insueta* zone in the Brasso formation, into the overlying *Globorotalia fohsi barisanensis* subzone in the Cipero and Brasso formations of Trinidad. It probably does not extend into the topmost part of the latter subzone. In Venezuela, it occurs in the middle part of the *Siphogenerina transversa* zone in the Pozón formation, and it has also been observed in the Bissex Hill formation of Barbados.

Globigerinoides transitoria Blow, new species
Text-figure 2, nos. 12-15

Diagnosis of species: Test bilobate. Penultimate and ultimate chambers nearly equal in size. Early chambers not inflated, arranged in a low trochoid spire and partly embraced (40-60 per cent) by the penultimate chamber. Early chambers lie within the general bilobate contour of the test. Sutures moderately incised. Apertures multiple, narrow short slits, confined to the sutures of the last and earlier chambers. Wall composed of more than one layer; wall surface cancellate but variable, the last chamber often less coarsely cancellate than the earlier chambers.

Holotype: Globigerinoides transitoria Blow, n. sp., text-fig. 2, nos. 12-13; sample no. R.M. 19280, T.L.L. Cat. No. 130296, Pozón formation, *Siphogenerina transversa* zone, auger line near Pozón, eastern Falcón, Venezuela. Deposited in the Cushman Collection (no. 64591), U. S. National Museum, Washington, D. C.

Remarks: The species shows rather variable morphology, and shows forms that are transitional to *Globigerinoides bispherica* and *Biorbulina bilobata.*

Occurrence: This form becomes fairly abundant in the uppermost part of the *Globigerinatella insueta* zone in the Cipero and Brasso formations of Trinidad, but does not persist into the overlying *Globorotalia fohsi barisanensis* subzone. In Venezuela, it occurs in the middle part of the *Siphogenerina transversa* zone. The species has also been observed in the Bissex Hill formation of Barbados.

Subfamily ORBULININAE

Genus **Orbulina** d'Orbigny, 1839, emend. Blow

Candorbulina JEDLITSCHKA, 1934.
Candeina d'Orbigny. – JEDLITSCHKA, 1934 (part).

Genotype: Orbulina universa d'Orbigny, 1839.

Emended diagnosis: Test usually spherical, with early stages like *Globigerina.* Last chamber globular, partially or completely enveloping the earlier ones. Apertures multiple, often a series of rounded openings that are distributed over the area of the last chamber; some but not all of the apertures may be present in the suture separating the last chamber from the earlier ones. Wall calcareous, composed of more than one layer, with numerous regularly arranged minute perforations. Surface finely or coarsely cancellate.

Remarks: Two species of this genus are now recognised, as the author has removed *"Orbulina" bilobata* (d'Orbigny) to a new genus, *Biorbulina.*

Orbulina universa d'Orbigny
Text-figure 2, nos. 8-9

Orbulina universa D'ORBIGNY, 1839, in SAGRA, R. DE LA, *Histoire physique, politique et naturelle de l'Île de Cuba; Foraminifères,* p. 2, pl. 1, fig. 1.

Remarks: In all the specimens studied that occurred between the *Globigerinatella insueta* zone and the *Globorotalia menardii* zone of Trinidad, the early *Globigerina* stage was always present. There is a tendency for these early chambers to become very fragile and reduced in size, but there are always three or four chambers in the last whorl. The ventral apertures of the early chambers are large semicircular openings with raised crescentic lips.

Occurrence: In Trinidad, the species ranges from the topmost part of the *Globigerinatella insueta* zone in the Brasso formation to the Recent. In Venezuela, it first appears in the middle part of the *Siphogenerina transversa* zone, and occurs throughout the Pozón formation.

Orbulina suturalis Bronnimann, emend. Blow
Text-figure 2, nos. 5-7

Orbulina universa d'Orbigny of authors (part).
Candorbulina universa JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., vol. 65, p. 21.
Candeina triloba JEDLITSCHKA, 1934 (part), ibid., p. 24, text-fig. 13.
Orbulina suturalis BRONNIMANN, 1951 (part), Contr. Cushman Found. Foram. Res., vol. 2, pt. 4, p. 135, text-fig. 2, nos. 1-2, 5-8, 10; text-fig. 3, nos. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, nos. 2-4, 7-12, 15-16, 19-22.

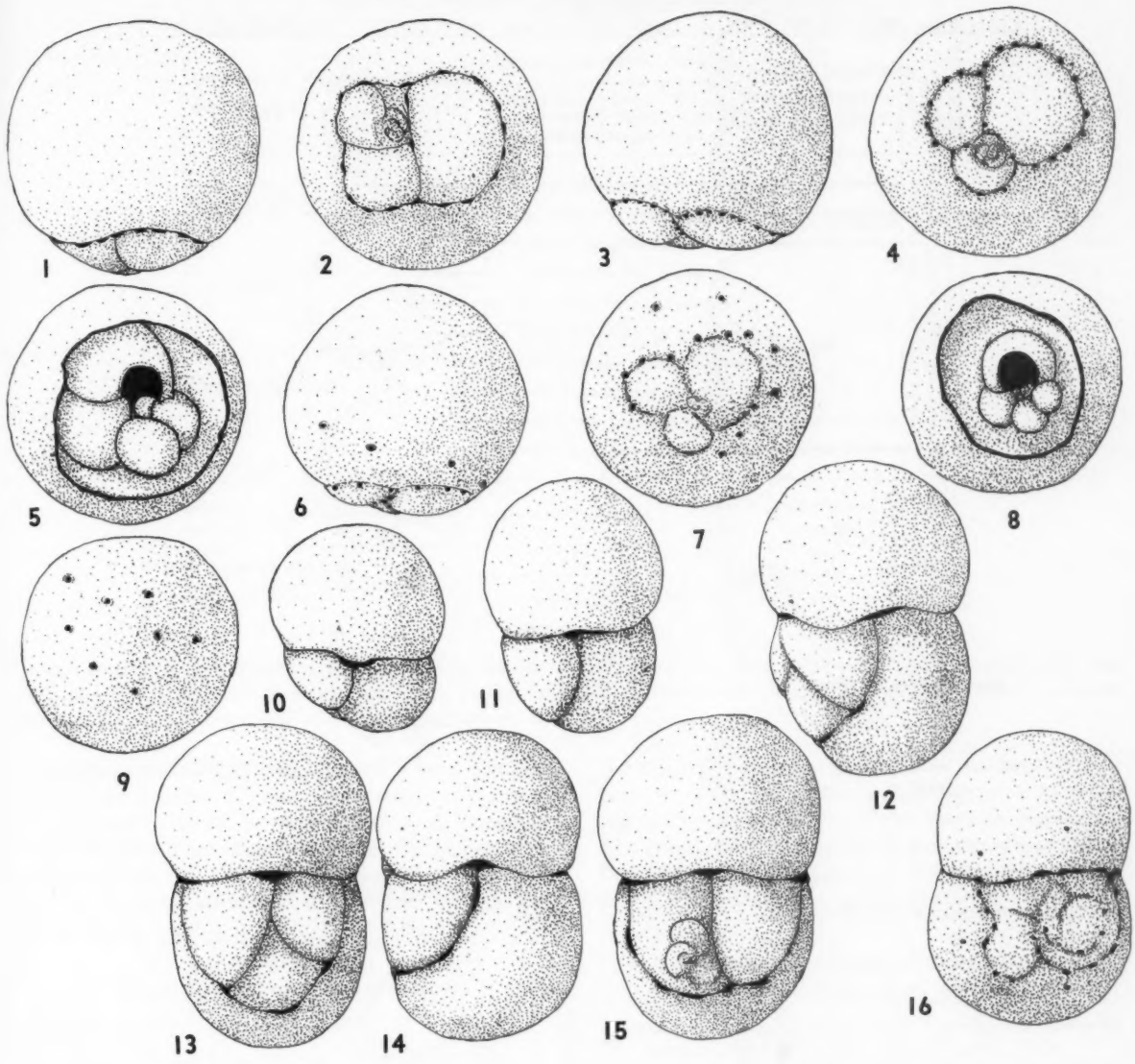
Since the writer has removed from this species those forms in which the apertural pores are confined to the sutural positions and are not distributed over the area of the last chamber, it becomes necessary to emend Bronnimann's diagnosis of *Orbulina suturalis.*

Emended diagnosis: Last chamber globular, not entirely enveloping the early part of the test. Tests show all transitions from forms in which the last chamber envelops about 75 per cent of the earlier part to forms in which the earlier chambers are only just visible. Apertures are subcircular or circular pore-like openings distributed over the area of the last chamber; some but not all may be present in the suture separating the last chamber from the penultimate and earlier chambers. Wall rather coarsely cancellate, with numerous regularly arranged minute perforations. Wall calcareous, composed of more than one layer.

Holotype: Orbulina suturalis Bronnimann, 1951, op. cit., text-fig. 4, nos. 15-16, 20; Miocene, *Globorotalia menardii* zone, Trinidad, B.W.I. Deposited in the Cushman Collection (no. 64181), U. S. National Museum, Washington, D. C.

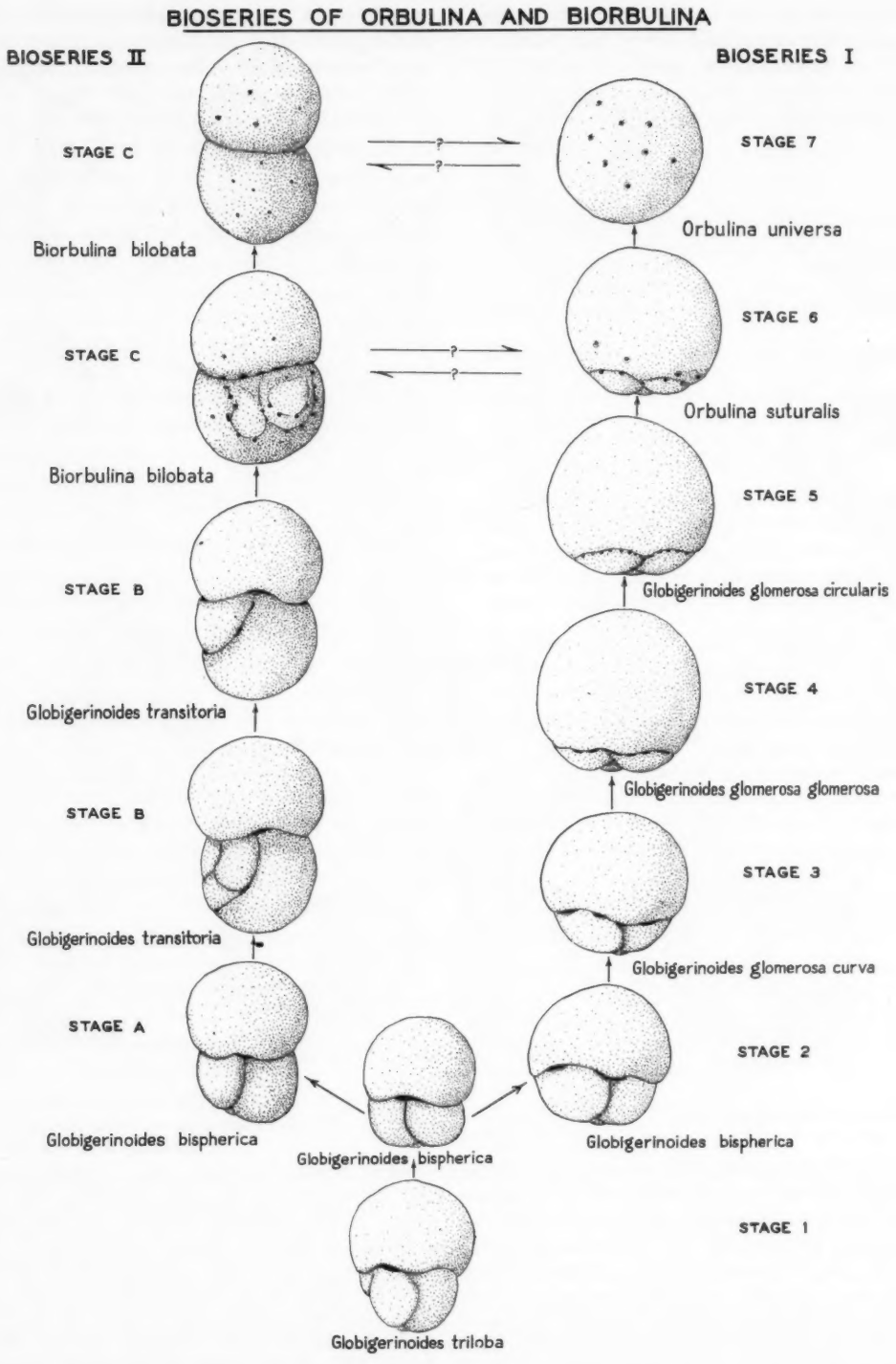
Remarks: Bronnimann's figured holotype shows a number of apertual pores distributed over the area of the last chamber. He illustrates a number of other forms from the Cipero formation, showing many transitions from forms in which the early part is clearly visible to others in which the last chamber almost completely embraces the earlier part.

Occurrence: The range of the species must now be extended downward into the top part of the *Globigerinatella insueta* zone in the Cipero and Brasso formations of Trinidad. In eastern Falcón, Venezuela,



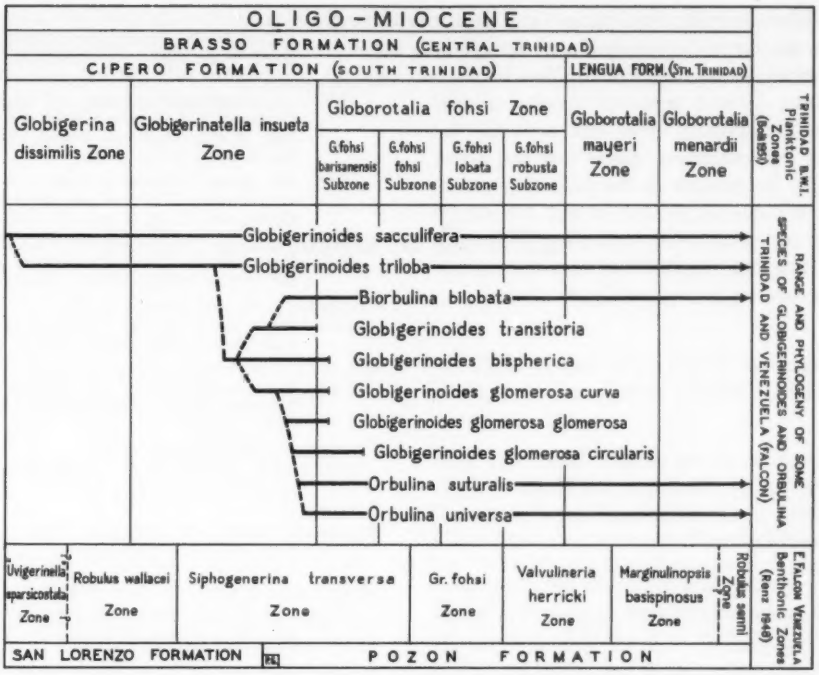
TEXT-FIGURE 2

All from the *Siphogenerina transversa* zone, Pozón formation, eastern Falcón, Venezuela; nos. 1-5 from sample R.M. 19285 (T.L.L. Cat. No. 130301); nos. 6-9 from sample R.M. 19293 (T.L.L. Cat. No. 130296), occurring with *Globorotalia fohsi barisanensis;* nos. 10-16 from sample R.M. 19280 (T.L.L. Cat. No. 130296), occurring with *Globigerinatella insueta;* all × ca. 60. 1-2, *Globigerinoides glomerosa glomerosa* Blow, n. subsp., side and spiral views. 3-4, *Globigerinoides glomerosa circularis* Blow, n. subsp., holotype, side and spiral views. 5-7, *Orbulina suturalis* Bronnimann: 5, umbilical view of specimen with last chamber opened; 6-7, side and spiral views. 8-9, *Orbulina universa* d'Orbigny: 8, umbilical view of specimen with last chamber opened; 9, dorsal view. 10-11, forms intermediate between *Globigerinoides bispherica* Todd and *Globigerinoides transitoria* Blow, n. sp., side views. 12-15, *Globigerinoides transitoria* Blow, n. sp.: 12, 14, side views; 13, 15, spiral views (12-13, holotype). 16, primitive form of *Biorbulina* Blow, n. gen., referred to *Biorbulina bilobata* (d'Orbigny).



TEXT-FIGURE 3

Bioseries showing origin and evolution of *Orbulina* and *Biorbulina;* the "central types" of each stage are illustrated, but every gradation exists between adjacent stages. All figures × ca. 40.



TEXT-FIGURE 4

Chart showing ranges of some species of *Globigerinoides, Orbulina* and *Biorbulina* in Trinidad and Venezuela and their phylogeny; a preliminary correlation of Renz's (1948) biozones of Falcón with the biozones of Bolli (1951) is shown diagrammatically. (Note: PG = Policarpio greensand member.)

Orbulina suturalis first appears above the Policarpio greensand member (*Siphogenerina transversa* zone) in the basal part of the Pozón formation. *Orbulina suturalis* probably became extinct in the Upper Miocene or basal Pliocene. It shows maximum abundance in the Lengua formation of Trinidad and in the *Valvulineria herricki* zone in Venezuela.

Genus **Biorbulina** Blow, new genus

Candeina d'Orbigny. – Jedlitschka, 1934 (part).

Genotype: Globigerina bilobata d'Orbigny, 1846.

Diagnosis of genus: Test bilobate, with ultimate and penultimate chambers nearly spherical and similar in size. Penultimate chamber partially or completely embracing the earlier ones. Apertures multiple, a series of rounded openings that are distributed irregularly over the area of the last and penultimate chambers; some but not all of the apertures may be present in the sutures between the last, penultimate and earlier chambers. Wall calcareous, composed of more than one layer. Surface cancellate, with numerous regularly arranged minute perforations.

Remarks: The new genus *Biorbulina* has been erected because of its distinctive morphology and its independent evolution from *Globigerinoides bispherica*. The penultimate chamber embraces the earlier chambers, whereas in *Orbulina* it is the ultimate chamber which embraces all the earlier chambers.

Biorbulina bilobata (d'Orbigny)
Text-figure 2, no. 16

Globigerina bilobata d'Orbigny, 1846, *Foraminifères fossiles du bassin tertiaire de Vienne*, p. 164, pl. 9, figs. 11-14.

Globigerina ovoidea Seguenza, 1880, R. Accad. Lincei Roma, Mem., vol. 6, p. 334, pl. 17, fig. 39.

Orbulina gemina Terrigi, 1891, Mem. Descr. Carta Geol. Ital., vol. 4, pt. 1, p. 103.

Candeina biloba Jedlitschka, 1934, Naturf. Ver. Brünn, Verh., vol. 65, pp. 22, 24, text-figs. 8-12.

Candeina triloba Jedlitschka, 1934 (part), ibid., pp. 22, 24, text-figs. 14-18, 20.

Orbulina universa d'Orbigny var. *bispherica* LeRoy, 1941, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 44, pl. 1, fig. 3.

Orbulina bilobata (d'Orbigny). – Bronnimann, 1951, Contr. Cushman Found. Foram. Res., vol. 2, pt. 4, p. 135, text-fig. 3, nos. 1-2, 9-10, 17, 19; text-fig. 4, nos. 5-6, 17-18.

Diagnosis: Test bilobate, with the ultimate and penultimate chambers similar in size, early chambers nearly or completely embraced by the penultimate chamber. Apertures multiple, often a series of circular or oval pores distributed irregularly over the area of the penultimate and last chambers. Some but not all of the apertures may be present in the sutural position. Sutures usually not deeply incised except the suture between the last and penultimate chamber. Wall composed of more than one layer, fairly coarsely cancellate, with numerous regularly arranged minute perforations.

Holotype: Globigerina bilobata d'Orbigny, 1846, op. cit., pl. 9, figs. 11-14; Tertiary, near Nussdorf, north of Vienna, Austria.

Remarks: The bilobate forms defined here were considered by Brady (1884), Cushman and Dorsey (1940), and LeRoy (1948) to be aberrant forms of typical *Orbulina* or *Candorbulina*.

Occurrence: The species first occurs in the uppermost part of the *Globigerinatella insueta* zone in the Brasso formation of Trinidad, and in the middle part of the *Siphogenerina transversa* zone in the Pozón formation of Falcón, Venezuela. It persists to the Recent, but never becomes as abundant as *Orbulina universa*.

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ABSTRACT: *A method has been discovered whereby calcareous objects can be changed, by what is believed to be a molecule-by-molecule replacement, from a carbonate to a fluoride composition without any change in gross structure. Evidence supporting this conclusion, and details of the method, are presented in this paper, as well as some suggestions for practical application.*

The conversion of calcite to fluorite

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In February, 1955, while a siliceous sample was being processed in the course of palynological work at the Field Research Laboratories of the Magnolia Petroleum Company, an interesting phenomenon was observed. This phenomenon, as detailed below, has been explained and demonstrated to numerous visitors to our Laboratories, chiefly geologists, biologists, chemists, and paleontologists from various industrial, academic and government institutions. The expression of surprise was so unanimous that it was decided a short article would be of interest to other scientists and may, as is true in our work, assist in the understanding of this interesting chemical process.

The curious phenomenon noted was that after the standard hydrofluoric acid treatment for the removal of the siliceous matter, a large amount of coarse debris remained in the sample. This debris was removed from the sample by sieving. Upon examination, the debris was found to be composed of shell fragments. This was surprising because, until this time, it had been assumed that the hydrofluoric acid, being a halogen acid, would perform the same function as hydrochloric acid and would dissolve the calcium carbonate. Since hydrofluoric acid had not eliminated the calcareous matter, an attempt was made to dissolve it by treatment with hydrochloric acid. It was rather startling to find that upon treatment with hydrochloric acid no reaction occurred. The sample was washed with distilled water, and an X-ray analysis was made. The analysis showed that the shell fragments were no longer composed of calcium carbonate, but were now composed of calcium fluoride. The following equation shows the reaction that had occurred:

$$CaCO_3 + 2HF \rightarrow CaF_2 + CO_2 + H_2O$$

This simple chemical equation in itself is not spectacular. Probably chemists have known about it for years, although it was not observed in a quick survey of chemical textbooks. However, it is suspected that the implications and possible applications in the fields of biology and geology have not been considered.

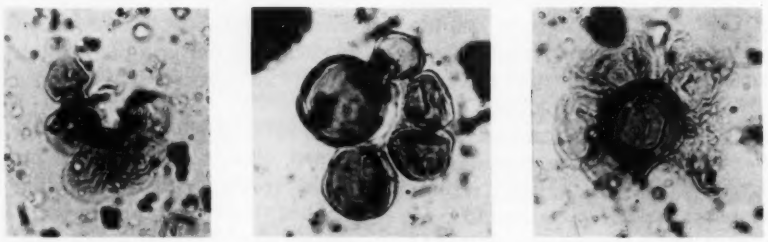
The field of palynology, with which the author is concerned, offers a good example of how the knowledge of this reaction will help to eliminate processing difficulties. Now that this reaction is understood, it is known that samples containing calcium carbonate must first be treated with hydrochloric acid or nitric acid if a higher concentration of polospores is desired. ("**Polospores**" is a new term here proposed as a convenient general name used to designate pollen and/or spores. Derivation: **Pol**len and/**or** **spores**.) The concentration of polospores on a microscope slide is probably the greatest processing problem palynologists encounter. Given a sufficient flora with which to work, the palynological results that can be obtained are limited only by the knowledge and the ability of the palynologist.

During the palynological investigations of the past several years, a group of very small foraminifera has been discovered. These are commonly referred to as "microforaminifera." They are abundant in some samples, absent from others, and some palynologists probably have never seen them. Wilson and Hoffmeister (1952) discuss these "microforaminifera" and state that "they have tests that are not destroyed by either hydrochloric or hydrofluoric acid." From the author's experience, this is true only when the hydrochloric acid treatment follows the hydrofluoric acid,

TABLE 1

SAMPLE ANALYSES

SAMPLE	BEFORE HF TREATMENT					AFTER HF TREATMENT				
	X-RAY ANALYSIS		SPECTROGRAPH ANALYSIS			X-RAY ANALYSIS		SPECTROGRAPH ANALYSIS		
	MAJOR	MINOR	MAJOR	MINOR	TRACE	MAJOR	MINOR	MAJOR	MINOR	TRACE
Mellita quinquiesperforata	Calcite	Quartz	Ca	Mg	Si	Fluorite	—	Ca	Mg	—
Arca incongrua	Aragonite	—	Ca	—	Si Al	Fluorite	—	Ca	—	Al
Donax variabilis	Aragonite	—	Ca	—	—	Fluorite	—	Ca	—	—
North Atlantic *Globigerina* sp.	Calcite	Quartz	Ca	Mg Fe	Al Si	Fluorite	—	Ca	—	Mg Al Fe
Cretaceous *Globigerina* sp.	Calcite	Quartz	Ca	Mg Fe	Al Si	Fluorite	—	Ca	Mg Al Fe	—

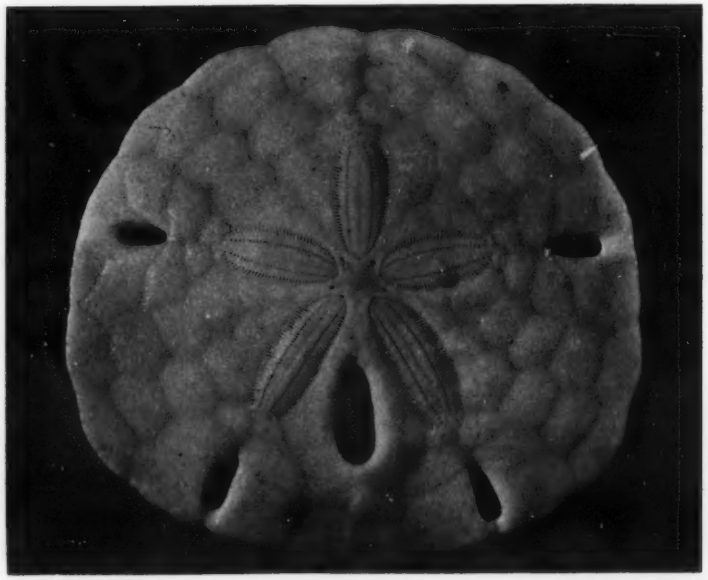


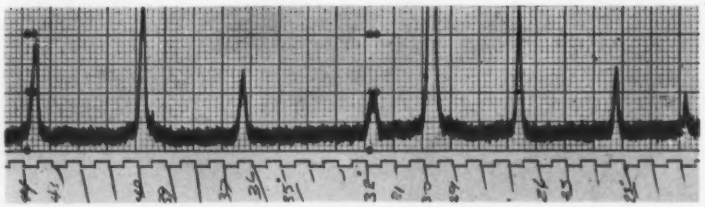
TEXT-FIGURE 1

Microfossils extracted from Cretaceous sediments, which are believed to be fungal in origin rather than "microforaminifera." Size range 25-60μ.

and is a result of the tests having been previously fluoritized and being therefore insoluble in hydrochloric acid. In the same paper, Wilson and Hoffmeister detail their method. According to the information presented, samples are treated only with hydrofluoric acid. No mention is made of hydrochloric acid treatment. Samples have been treated in our laboratory with hydrofluoric acid first, and these "microforaminifera" have been observed. The same samples pre-treated with hydrochloric acid reveal no trace of these organisms. There appears to be a conflict between Wilson and Hoffmeister's results and those of the author. This conflict is believed to be only apparent, however. In reality, the point of confusion may be a difference in interpretation of certain microfossils. In the photomicrographs that accompany the above-mentioned article (Wilson and Hoffmeister, 1952, text-figs. 22 and 23), two microfossils are interpreted as "microforaminifera," which in the author's opinion is a doubtful identification. These microfossils have frequently been observed in our samples that were treated first with hydrochloric acid. It is believed that they are probably multicellular fungi spores, similar to those found in the genus *Helminthosporium*. Text-figure 1 shows examples of a few of these microfossils extracted from Cretaceous sediments of Texas.

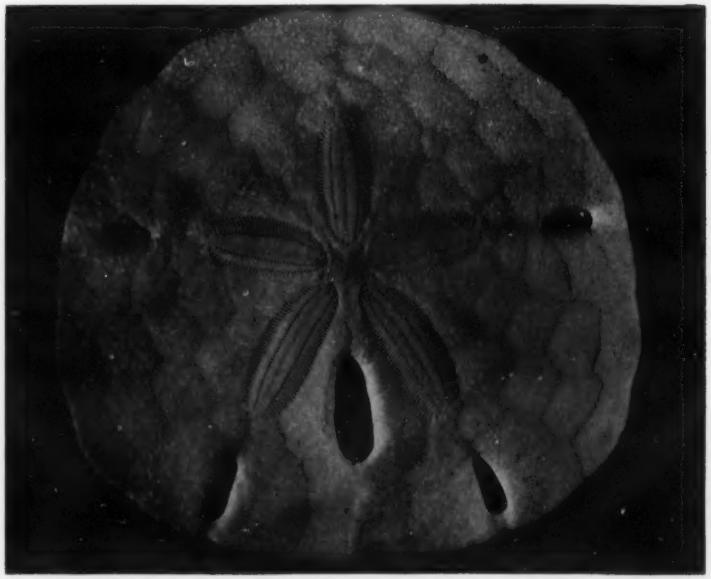
Hoffmeister (1955, p. 157) states: "Foraminifera have *calcareous* or siliceous shells, yet their remains are encountered in residues prepared with *hydrofluoric acid which should ordinarily destroy these coverings.* It is believed that some have not only calcareous or siliceous outer shells but also acid resistant inner coats which protect their individual chambers." (Italics are those of the author.)

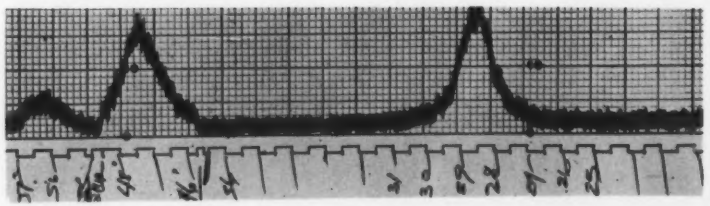




TEXT-FIGURE 2

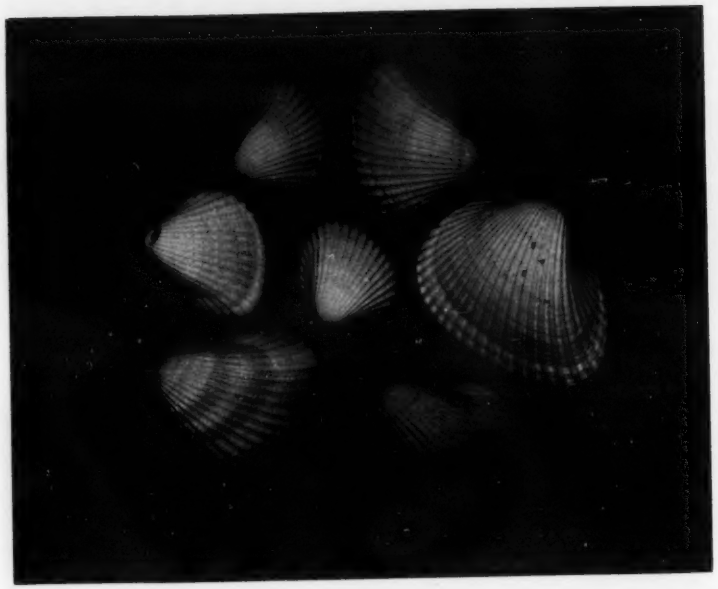
Mellita quinquiesperforata Leske, before hydrofluoric acid treatment (calcite). × ca. 1.5.

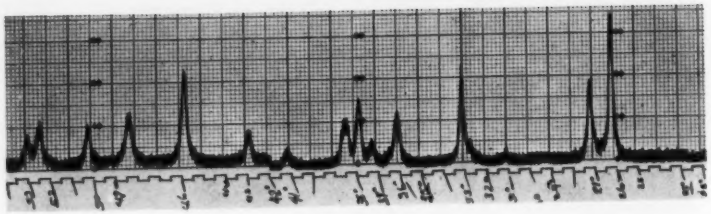




TEXT-FIGURE 3

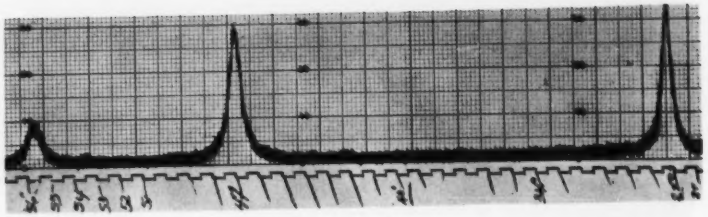
Mellita quinquiesperforata Leske, after hydrofluoric acid treatment (fluorite). × ca. 1.5.





TEXT-FIGURE 4

Arca incongrua Say, before hydrofluoric acid treatment (aragonite). × ca. 1.

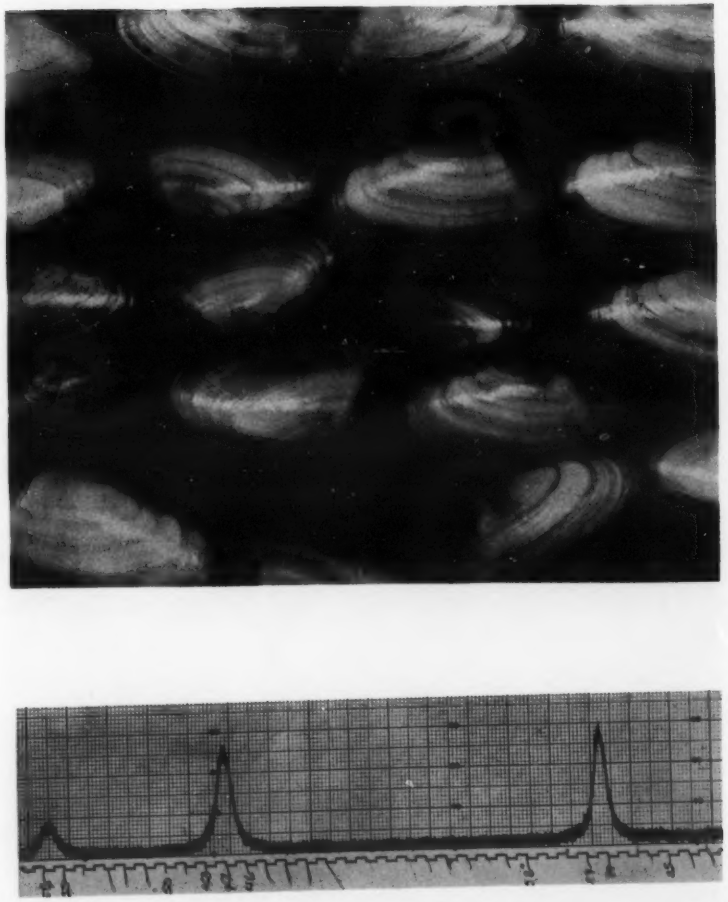


TEXT-FIGURE 5

Arca incongrua Say, after hydrofluoric acid treatment (fluorite). × ca. 1.

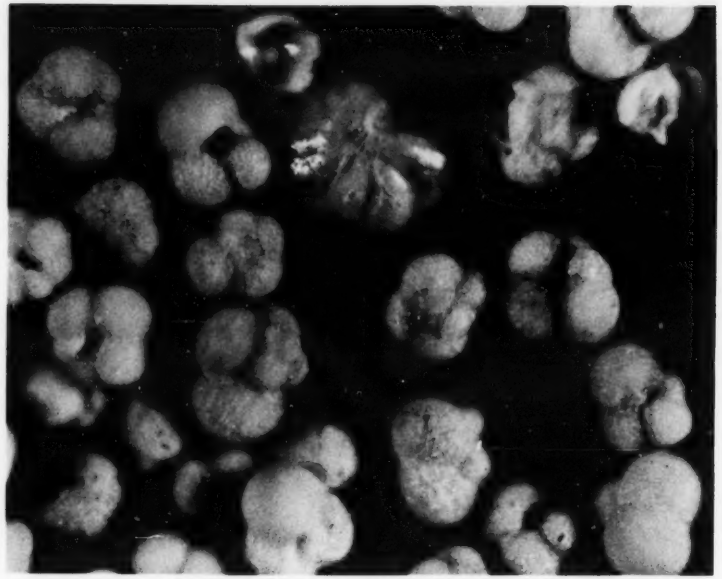
TEXT-FIGURE 6

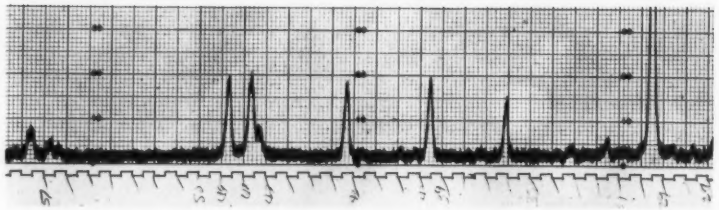
Donax variabilis Say, before hydrofluoric acid treatment (aragonite). × ca. 2.5.



TEXT-FIGURE 7

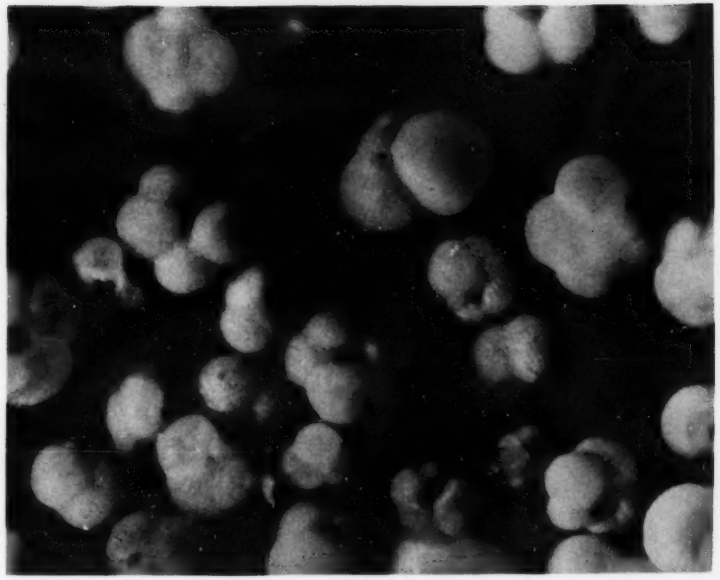
Donax variabilis Say, after hydrofluoric acid treatment (fluorite). × ca. 2.5.

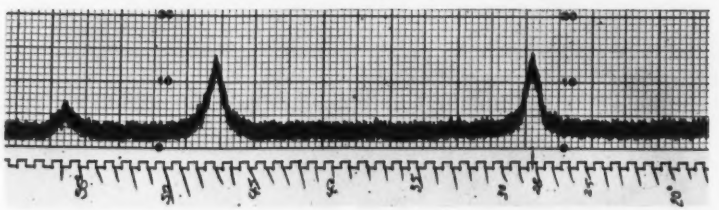




TEXT-FIGURE 8

Globigerina sp., before hydrofluoric acid treatment (calcite). × ca. 50.





TEXT-FIGURE 9

Globigerina sp., after hydrofluoric acid treatment (fluorite). × ca. 50.

Foraminiferal samples have been observed by the author under the microscope and then treated with hydrochloric acid. At no time were any "inner coats" observed after the hydrochloric acid treatment. Now that this chemical process is understood, it is no longer necessary to postulate "acid resistant inner coats," since in all probability they are calcite shells converted by hydrofluoric acid into fluorite.

In addition to simple conversion of calcite into fluorite, this discovery has other implications. The most amazing part of this replacement is the fact that it appears to be a *molecule-by-molecule replacement of the carbonate by the fluoride ion without any alteration of the gross structure of the object replaced.*

The figures accompanying this paper illustrate this point. Text-figures 2 to 9 show calcareous shells before and after hydrofluoric acid treatment, together with the X-ray pattern obtained from each. Table 1 gives the X-ray and spectrographic analyses of various samples before and after hydrofluoric acid treatment. The X-ray analyses were made with a tube having a copper target. The scale used in the illustrations is the angle 2θ.

Text-figure 2 shows a specimen of *Mellita quinquiesperforata* before treatment. Text-figure 3 shows the same specimen after the full-strength treatment (see discussion of methods, below). The obvious differences are the presence, on the surface of the treated specimen, of small crystals, which are easily removed by washing, and an emphasis of most of the suture lines. The specimen weighed 10.14 grams before and 6.28 grams after treatment. The molecular weight of calcium carbonate is 100.09 and that of calcium fluoride is 78.08 or, roughly, a ratio of 4:3. The difference in weight of the specimen before and after treatment was found to be greater than the expected 4:3 ratio. However, the interior of the echinoid contained some sand before treatement. The sand, of course, was dissolved by the hydrofluoric acid. If allowance is made for roughly 1½ grams of extraneous siliceous matter, the correct ratio is obtained. The X-ray analysis below text-figure 2 indicates that the major element is calcite and that a trace of quartz is present. Table 1 shows that magnesium is found in minor quantities in the sample, along with calcium from the calcium carbonate and silicon from the sand. After hydrofluoric acid treatment the quartz was no longer present in the X-ray or spectrographic analyses, but the magnesium remained.

Text-figure 4 shows a collection of *Arca incongrua* shells before treatment. The X-ray analysis indicates that the shells are composed of aragonite. Text-figure 5 shows the same collection after treatment, and the X-ray analysis indicating that the chemical composition is calcium fluoride. Table 1 indicates that traces of silicon and aluminum were present before hydrofluoric acid treatment, and a trace of aluminum afterwards. Except for the shells appearing much cleaner after treatment, the only noticeable difference was a small crack in the largest shell. This was caused by the use of too concentrated a solution of hydrofluoric acid. Seven shells of *Arca incongrua* weighed 10.11 grams before and 7.51 grams after treatment. Here again, the ratio between the molecular weights of calcium carbonate and calcium fluoride is roughly maintained if allowance is made for extraneous material being present.

Text-figure 6 shows a collection of *Donax variabilis* shells before hydrofluoric acid treatment, with an X-ray analysis beneath the figure which indicates that the shells are composed of aragonite. The suggestion was made that possibly some of the shells might originally have been composed of fluorite. In order to dispel any possible doubt, only specimens in which both valves were present were used in this experiment. After photographing the shells, the valves were separated and one valve of each shell was processed and one left unprocessed. The valves that were treated with hydrofluoric acid are shown in text-figure 7. An X-ray analysis shows that the shells are composed of fluorite. Before hydrofluoric acid treatment, nineteen valves of *Donax variabilis* weighed 3.11 grams. After treatment they weighed 2.24 grams. It can be seen that a considerable amount of fracturing took place in some of the shells. This was a result of the use of a highly concentrated (48%) solution of hydrofluoric acid. A second experiment, performed with more caution, altered the chemical composition without the development of fractures. Text-figure 7 demonstrates the effects, such as the production of artificial features in fossils, that may occur when the method is not used cautiously.

Text-figure 8 is a photomicrograph of some *Globigerina* specimens collected from the North Atlantic Ocean. The X-ray analysis shows that they are composed of calcite, and that there is a trace of quartz present in the sample. The spectrographic analysis indicates that, in addition to calcium, small quantities of silicon, magnesium, iron and aluminum are also present. Text-figure 9 shows a sample of these *Globigerina* specimens after hydrofluoric acid treatment, with the X-ray analysis indicating fluorite. The silicon has disappeared, but small amounts of iron, aluminum, and magnesium are still present. The sample weighed 0.51

gram before treatment and 0.46 gram after treatment. Several samples of Cretaceous *Globigerina* were also treated. After treatment, the morphological features of these organisms were as good as, if not better than, before treatment. Apparently the hydrofluoric acid treatment had produced a "cleaning" effect.

The four examples cited above illustrate the results as well as the principle of this phenomenon. The method involved is quite simple. All that is necessary is the proper concentration of hydrofluoric acid. The sample which is to be fluoritized is immersed in hydrofluoric acid for a period of time ranging from one minute to twenty-four hours. The time depends upon the size and the porosity of the sample and the strength of the hydrofluoric acid solution. Samples that are very small, such as the *Globigerina* demonstrated above, can be treated with full strength (48%) hydrofluoric acid. The reaction is almost instantaneous. With large shells such as *Arca incongrua*, a weak solution (6%) was necessary at the beginning. Over a period of twelve hours the strength of the solution was gradually increased to about 24%. With shells of little porosity, such as *Donax variabilis*, a weak solution (6%) must be used for about twenty-four hours. Otherwise, as illustrated in text-figure 6, fracturing will occur.

The fracturing of certain shells was thought at first to be a result of stress or strain within the structure caused by the change in the molecular form. However, careful observation of the specimen during treatment suggests that fracturing is caused by the gaseous carbon dioxide that is given off during the reaction between the calcium carbonate and the hydrofluoric acid. This gas must be liberated; if it is not easily expelled into the liquid medium, it builds up pressure within the structure and finally fractures the specimen. Where fractures occurred, larger amounts of gas bubbles were emitted than were being emitted from the ordinary pores.

Dolomite was also treated with hydrofluoric acid. Porous dolomite was completely fluoritized, but non-porous dolomite was fluoritized only to a shallow depth. Non-porous limestones also were treated, with the same results. The effect of the hydrofluoric acid treatment on calcite crystals was also investigated. Large crystals of calcite were broken up by the acid into smaller and smaller crystals until what appeared to be an amorphous mass of calcium fluoride remained.

In the field of paleontology, this phenomenon should be of considerable value. First, it can be used to separate calcareous remains from siliceous sediments. Second, it can be used for cleaning Recent and fossil shells. Third, it can be used to bring out details of structures that are otherwise obscured.

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Bibliography and index to new genera and species of Ostracoda for 1954

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Approximately forty-nine papers pertaining to ostracodes are known to have been published during the year 1954. This represents a decrease from the eighty-one ostracode papers published in 1953 (see Levinson, 1955, Micropaleontology, vol. 1, no. 3, pp. 273-286). In 1954, thirty-four new genera and subgenera were described, as opposed to thirty-four in 1953, fifty in 1952, twenty-three in 1951, and thirty in 1950. The stratigraphic distribution of the new genera proposed in 1954 is as follows: Paleozoic, twenty-four; Mesozoic, four; Cenozoic, four; Recent, one. During 1954, 220 new species were described, in contrast to the 271 new species described in 1953.

The writer is again grateful to the many ostracode workers who have generously supplied him with reprints of their papers and of other papers as they appeared. He is particularly indebted to Dr. Henry V. Howe, Mrs. Betty Kellett Nadeau, Dr. Harbans Puri, and Mr. Lee Gibson.

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MALKIN, D. S.

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MARTIN, G. P. R., AND WEILER, W.

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PURI, H. S.
1954*a* *Contribution to the study of the Miocene of the Florida Panhandle.* Florida, Geol. Survey, Bull., no. 36 (1953), pp. 1-345 (*Part III—Ostracoda,* pp. 217-345, pls. 1-17, text-figs. 1-4; and *Part II—Foraminifera,* pl. 15, fig. 5).

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1954 – *Zur Taxionomie und Chronologie der oberdevonischen Ostracoden.* Hesse, Landesamt Bodenforsch., Abh., vol. 9, pp. 1-286, pls. 1-5, 7 text-figs.

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1954 – *Stratigraphisch wichtige Ostracoden im "Kimmeridge" und tiefsten "Portland" NW-Deutschlands.* Pal. Zeitschr., vol. 38, no. 1/2, pp. 81-101, pls. 5-8, text-figs. 1-3.

SIMON, W., AND DAHMER, G.
1954 – *Zygobolba corbis (Ostrac.), Leitmarke für den Beginn des Mittel-Devons im Oberharz.* Senckenbergiana, vol. 34, no. 4/6, pp. 235-245, text-figs. 1-9.

SOHN, I. G.
1954*a* *Ostracoda from the Permian of the Glass Mountains, Texas.* U. S. Geol. Survey, Prof. Paper 264-A, pp. 1-24, pls. 1-5, 2 text-figs.

1954*b* *Paleocene Ostracoda from outcrops in Maryland.* Science, vol. 119, no. 3097, p. 656.

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1954 – *Postscript notes of the ostracode Trachyleberis.* Jour. Pal., vol. 28, no. 5, pp. 560-562.

SWAIN, F. M., AND ENGEL, P. L.
1954 – *Ostracoda.* In: *Study of nearshore Recent sediments and their environments in the northern Gulf of Mexico.* California, Univ., Scripps Inst. Oceanogr., Amer. Petr. Inst. Res. Proj. 51, 3rd Quart. Rept. 1954, pp. 7-8, table 2 (not considered publication).

TRESSLER, W. L.
1954*a* *Marine Ostracoda.* In: *Gulf of Mexico, its origin, waters, and marine life.* U. S. Dept. Interior, Fishery Bull. 89, pp. 1-604 (ostracodes, pp. 429-437).

1954*b* *Fresh-water Ostracoda from Texas and Mexico.* Washington Acad. Sci., Jour., vol. 44, no. 5, pp. 138-149, text-figs. 1-48, 1 table.

TRIEBEL, E.
1954*a* *Malm-Ostracoden mit amphidontem Schloss.* Senckenbergiana Lethaea, vol. 35, no. 1/2, pp. 3-16, pls. 1-4.

1954*b* *Loxoconchella n.g. (Crust., Ostr.).* Senckenbergiana Lethaea, vol. 35, no. 1/2, pp. 17-21, pls. 1-2.

WELLMAN, H. W.
1954 – *Marine Pliocene at Resolution Island, Dusky Sound, Fiordland (S156).* New Zealand Jour. Sci. Technol., Sec. B., vol. 35, no. 5, pp. 378-389.

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1954 – *Statistical methods and techniques for the measurement of average index ratios of ostracod carapaces.* Amer. Midland Nat., vol. 52, no. 1, pp. 149-153.

NEW SUBGENERA, GENERA AND SUPRAGENERIC CATEGORIES IN 1954

In the alphabetically arranged list of genera, the order of the items given in each entry is as follows: Name of the genus, its author and date; name of the type species, its author and date; page and figure in the reference in which the genus is proposed; stratigraphic horizon and geographic locality of the type species (in parentheses); range and habitat of the genus; family affiliation, if noted in the paper in which the new genus is described.

Abursus Loranger, 1954*a*; *A. beaumontensus* Loranger, 1954*a*; p. 194, pl. 2, figs. 5-6, 9-10 (Upper Devonian, Alberta, Canada); Upper Devonian, marine, Cytherellidae.

Amphicythere Triebel, 1954*a*; *A. semisulcata* Triebel, 1954*a*; p. 13, pl. 3, figs. 19-22; pl. 4, figs. 23-25 (Upper Jurassic, Germany); Upper Jurassic, Cytheridae, Progonocytherinae.

Amphizona Kesling and Copeland, 1954; *A. asceta* Kesling and Copeland, 1954; p. 154, pl. 1, figs. 1-31; pl. 2, figs. 1-4, 8-40 (Middle Devonian, New York); Middle Devonian, marine, Kirkbyidae.

BRACHYCYTHERINAE Puri, 1954*a*, new subfamily of Cytheridae; p. 248; erected to include: *Brachycythere* Alexander, 1933, and *Alatacythere* Murray and Hussey, 1942.

Ceratobairdia Sohn, 1954*a*; *C. dorsospinosa* Sohn, 1954*a*; pp. 5-6, pl. 1, figs. 27-32; pl. 2, figs. 17, 19 (Permian, Texas); Permian, marine, Bairdiidae.

Chapmanites Krömmelbein, 1954*b*; *C. crassus* Krömmelbein, 1954*b*; p. 202, pl. 5, figs. 67-69 (Middle Devonian, Australia); Middle Devonian, marine. "Die neue Gattung steht morphologisch etwa in der Mitte zwischen *Cavellina* und *Bairdiocypris.*"

Checontonomus Kesling, 1954*a*; *C. cophus* Kesling, 1954*a*; p. 578, pl. 59, figs. 1-7 (Middle Devonian, New York); Middle Devonian, marine, Entomoconchidae, Oncotechmoninae.

Cornikloedenia Henningsmoen, 1954*c*; *Drepanellina ventralis* Ulrich and Bassler, 1923 (Silurian, Maryland); Silurian, marine, Beyrichiidae, Kloedeniinae.

Coronakirkbya Sohn, 1954*a*; *C. fimbriata* Sohn, 1954*a*; pp. 10-11, pl. 5, figs. 1-6 (Permian, Texas); Mississippian?, Permian, marine, Kirkbyidae, Kirkbyinae.

Echinocythereis Puri, 1954*a; Cythereis garretti* Howe and McGuirt, 1935; p. 259, pl. 12, figs. 2-5, text-fig. 9a-b (Miocene, Florida); Eocene to Recent, marine, Cytheridae, Trachyleberinae.

Endolophia Kesling, 1954*b; E. chariessa* Kesling, 1954*b;* p. 174, pl. 2, figs. 1-4; pl. 3, figs. 1-14 (Middle Devonian, Ohio); Middle Devonian, marine, Barychilinidae.

Eobeyrichia Henningsmoen, 1954*c;* new subgenus of *Beyrichia; Beyrichia (E.) zygophora* Henningsmoen, 1954*c;* p. 22 (Silurian, Norway); Silurian, marine, Beyrichiidae.

EUCYTHERINAE Puri, 1954*a;* new subfamily of Cytheridae; p. 298; this subfamily is monotypic and consists of the type genus, *Eucythere* Brady, 1866.

Hermania Puri, 1954*a* (non Monterosato, 1884, Moll.); *H. reticulata* Puri, 1953*d;* p. 267, pl. 11, figs. 8-9, text-fig. 9g-h (Miocene, Florida); Miocene, marine, Cytheridae, Hemicytherinae.

KELLETTININAE Sohn, 1954*a;* new subfamily of Kirkbyidae; p. 14; erected to include *Kellettina* Swartz, 1936, *Kindlella* Sohn, 1954, and *Semipetasus* Sohn, 1954, and provisionally *Editia* Brayer, 1952, and *Strepula* Jones and Holl, 1886.

Kindlella Sohn, 1954*a; K. fissiloba* Sohn, 1954*a;* p. 16, pl. 2, fig. 12; pl. 3, figs. 22-27; pl. 4, fig. 13 (Permian, Texas); Carboniferous, Permian, marine, Kirkbyidae, Kellettininae.

Loxoconchella Triebel, 1954*b; Loxoconcha honoluliensis* Brady, 1880; pp. 18-19, pl. 1, figs. 1-6; pl. 2, fig. 7 (Recent, Australia); Recent, marine, Cytheridae, Loxoconchinae.

Maternella Rabien, 1954, new subgenus of *Richterina; Richterina costata* (Richter) var. *dichotoma* Paeckelmann, 1913; p. 134, pl. 1, figs. 8-9; pl. 5, fig. 41 (Upper Devonian, Germany); Upper Devonian, marine, Entomozoidae, Entomozoinae.

Mitrobeyrichia Henningsmoen, 1954*c; Beyrichia jonesii* Boll, 1856; p. 27 (Silurian, Germany); Silurian, marine, Beyrichiidae.

Murrayina Puri, 1954*a; M. howei* Puri, 1954*a;* p. 255, pl. 12, figs. 9-10, text-fig. 8g-h (Miocene, Maryland); Miocene, marine, Cytheridae, Trachyleberinae.

Nanopsis Henningsmoen, 1954*a; Beyrichia nanella* Moberg and Segerberg, 1906; p. 54, pl. 1, fig. 1 (Lower Ordovician, Norway and Sweden); Lower Ordovician, marine, family uncertain.

Neobeyrichia Henningsmoen, 1954*c; Beyrichia buchiana* Jones, 1855; pp. 25-26 (Silurian, Germany); Silurian and Devonian, marine, Beyrichiidae.

Nodibeyrichia Henningsmoen, 1954*c; Beyrichia bronni* Reuter, 1885; pp. 26-27 (Silurian, Germany); Silurian, marine, Beyrichiidae.

ONCOTECHMONINAE Kesling, 1954*a;* new subfamily of Entomoconchidae; p. 576; erected to include: *Oncotechmonus* Kesling, 1954*a,* and *Checontonomus* Kesling, 1954*a.*

Oncotechmonus Kesling, 1954*a; O. chemotus* Kesling, 1954*a;* pp. 576-577, pl. 59, figs. 8-21, text-fig. 1 (Middle Devonian, New York); Middle Devonian, marine, Entomoconchidae, Oncotechmoninae.

Orionina Puri, 1954*a; Cythere vaughani* Ulrich and Bassler, 1928; p. 253, pl. 12, figs. 15-16, text-fig. 8a-c (Miocene, Maryland); Eocene to Recent, marine, Cytheridae, Trachyleberinae.

Procytheridae Peterson, 1954; *P. exempla* Peterson, 1954; p. 171, pl. 19, figs. 6-14, text-fig. 2e-f (Upper Jurassic, Montana and Wyoming); Upper Jurassic, marine, Cytheridae.

Protobuntonia Grékoff, 1954*a; P. numidica* Grékoff, 1954*a;* p. 489, text-fig. 1 (Upper Cretaceous, Lower Senonian, Algeria); Upper Cretaceous, marine, Trachyleberidae.

Sanniolus Sohn, 1954*a; S. sigmoides* Sohn, 1954*a;* pp. 17-18, pl. 5, figs. 9-13 (Permian, Texas); Permian, marine, Miltonellidae.

Semipetasus Sohn, 1954*a; S. signatus* Sohn, 1954*a;* p. 16, pl. 4, fig. 12; pl. 5, figs. 7-8 (Permian, Texas); Permian, marine, Kirkbyidae, Kellettininae.

Signetopsis Henningsmoen, 1954*c; S. quadrilobata* Henningsmoen, 1954*c;* pp. 61-62, pl. 7, figs. 1-9; pl. 8, fig. 25 (Silurian, Norway); Silurian, marine, Primitiopsiidae.

Spinosa Loranger, 1954*b;* subgenus of *Cytheridea; nomen nudum.*

TREPOSELLINAE Henningsmoen, 1954*c;* new subfamily of Beyrichiidae; p. 33; erected to include the following genera: *Treposella* Ulrich and Bassler, 1913; *Bolbiprimitia* Kay, 1940; *Hibbardia* Kesling, 1953; *Phlyctiscapha* Kesling, 1953; and *?Mesomphalus* Ulrich and Bassler, 1913.

Truncata Loranger, 1954*b;* subgenus of *Candona; nomen nudum.*

Trypetera Kesling, 1954*b; T. barathrota* Kesling, 1954*b;* p. 178, pl. 2, figs. 8-12; pl. 3, figs. 15-16 (Middle Devonian, Ohio); Middle Devonian, marine, Barychilinidae.

Velibeyrichia Henningsmoen, 1954*c; Beyrichia moodeyi* Ulrich and Bassler, 1908; pp. 24-25 (Silurian, West Virginia); Silurian and Lower Devonian, marine, Beyrichiidae.

Volkina Rabien, 1954, new subgenus of *Richterina; Entomis (Nehdentomis) zimmermanni* Volk, 1939; p. 108, pl. 2, fig. 14; pl. 4, figs. 33-34 (Upper Devonian, Germany); Upper Devonian, marine, Entomozoidae, Entomozoinae.

Waldeckella Rabien, 1954; *W. erecta* Rabien, 1954; p. 149, pl. 1, fig. 10; pl. 5, fig. 44 (Upper Devonian, Germany); Upper Devonian, marine, family uncertain.

NEW SPECIES, SUBSPECIES AND VARIETIES IN 1954

Abursus beaumontensus Loranger, 1954*a;* p. 194, pl. 2, figs. 5-6, 9-10 (Upper Devonian, Alberta, Canada); Cytherellidae.

Abursus biltmorensus Loranger, 1954*a*; p. 194, pl. 2, figs. 1-2, 23-24 (Upper Devonian, Alberta, Canada); Cytherellidae.

Abursus duvernaius Loranger, 1954*a*; pp. 194-195, pl. 1, figs. 21-22 (Upper Devonian, Alberta, Canada); Cytherellidae.

Aechmina paeckelmanni Rabien, 1954; p. 166, pl. 2, fig. 20; pl. 5, fig. 47 (Upper Devonian, Germany); Drepanellidae, Aechmininae.

Amphicythere semisulcata Triebel, 1954*a*; pp. 13-15, pl. 3, figs. 19-22; pl. 4, figs. 23-25 (Upper Jurassic, Germany); Cytheridae, Progonocytherinae.

Amphissites albertensi Loranger, 1954*a*; p. 196, pl. 1, figs. 13-14 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Amphissites beaumontensi Loranger, 1954*a*; p. 196, pl. 2, figs. 31-32 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Amphissites duvernai Loranger, 1954*a*; pp. 196-197, pl. 1, figs. 27-28 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Amphissites knighti Sohn, 1954*a*; p. 14, pl. 3, figs. 13-14 (Permian, Texas); Kirkbyidae, Amphissitinae.

Amphissites rowei Coley, 1954; p. 462, pl. 53, figs. 4-5 (Middle Devonian, New York); Kirkbyidae.

Amphizona asceta Kesling and Copeland, 1954; pp. 154-159, pl. 1, figs. 1-31; pl. 2, figs. 1-4, 8-40 (Middle Devonian, New York); Kirkbyidae.

Aparchites buchanensis Krömmelbein, 1954*b*; pp. 196-197, pl. 1, figs. 4-6 (Middle Devonian, Australia).

Aparchites obliquus Krömmelbein, 1954*b*; p. 197, pl. 1, figs. 7-9 (Middle Devonian?, Australia).

Aparchites regularis Krömmelbein, 1954*b*; pp. 195-196, pl. 1, figs. 1-3 (Middle Devonian, Australia).

Aparchitocythere compressa Peterson, 1954; p. 168, pl. 18, figs. 10-14, text-fig. 2c-d (Upper Jurassic, Wyoming and South Dakota); Cytheridae.

Aparchitocythere elongata Peterson, 1954; pp. 168-169, pl. 18, figs. 15-18 (Upper Jurassic, Wyoming and South Dakota); Cytheridae.

Bairdia biltmorensa Loranger, 1954*a*; p. 193, pl. 2, figs. 3-4 (Upper Devonian, Alberta, Canada); Bairdiidae.

Bairdia chipolensis Puri, 1954*a*; p. 223, pl. 1, fig. 2, text-fig. 1c (Miocene, Florida); Bairdiidae, Bairdiinae.

Bairdia desioi Conti, 1954; p. 224, pl. 13, fig. 7 (Lower Jurassic, Italy).

Bairdia postacutata Conti, 1954; p. 224, pl. 12, figs. 15-16 (Lower Jurassic, Italy).

Bairdia? proboscidata Conti, 1954; p. 225, pl. 13, fig. 8 (Lower Jurassic, Italy).

Bairdia? pruniseminata Sohn, 1954*a*; pp. 4-5, text-figs. 1a-d, 2; pl. 1, figs. 1-7 (Permian, Texas); Bairdiidae.

Bairdia ruggerii Conti, 1954; p. 223, pl. 12, fig. 14 (Lower Jurassic, Italy).

Bairdia saxifraga Krömmelbein, 1954*a*; pp. 249-250, pl. 1, fig. 2a-d (Devonian, Germany).

Bairdia singularis Krömmelbein, 1954*a*; pp. 248-249, pl. 1, fig. 1a-d (Devonian, Germany).

Bairdoppilata willisensis Puri, 1954*a*; p. 225, pl. 1, figs. 5-8, text-fig. 1e-h (Miocene, Florida); Bairdiidae, Bairdiinae.

Balantoides biltmorensus Loranger, 1954*a*; pp. 197-198, pl. 1, figs. 9-10 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Balantoides fribourgellus Loranger, 1954*a*; p. 198, pl. 1, figs. 3, 4 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Barychilina periptyches Kesling, 1954*b*; pp. 173-174, pl. 2, figs. 5-6 (Middle Devonian, Ohio); Barychilinidae.

Basslerites tenmilecreekensis Puri, 1954*a*; p. 280, pl. 8, figs. 13-15, text-fig. 11m (Miocene, Florida); Cytheridae, Cytherettinae.

Beyrichia (Beyrichia) kiaeri Henningsmoen, 1954*c*; pp. 43-44, pl. 3, figs. 13-15; pl. 8, fig. 8 (Silurian, Norway); Beyrichiidae.

Beyrichia (Eobeyrichia) zygophora Henningsmoen, 1954*c*; p. 39, pl. 1, figs. 10-14; pl. 8, fig. 3 (Silurian, Norway); Beyrichiidae.

Beyrichia (Eobeyrichia) paucituberculata Henningsmoen, 1954*c*; pp. 37-38, pl. 1, figs. 1-3; pl. 8, fig. 1 (Silurian, Norway); Beyrichiidae.

Beyrichia (Neobeyrichia) ringerikensis Henningsmoen, 1954*c*; pp. 44-46, pl. 3, figs. 16-21, pl. 8, fig. 9 (Silurian, Norway); Beyrichiidae.

Beyrichia (Eobeyrichia) skienensis Henningsmoen, 1954*c*; pp. 39-40, pl. 1, figs. 15-16; pl. 8, fig. 4 (Silurian, Norway); Beyrichiidae.

Beyrichia (Eobeyrichia) zygophora Henningsmoen, 1954*c*; p. 38, pl. 1, figs. 4-9; pl. 8, fig. 2 (Silurian, Norway); Beyrichiidae.

Bolbina tuberculata Henningsmoen, 1954*b*; p. 78, pl. 1, figs. 3-5; text-fig. 2 (Upper Ordovician, Norway); Sigmoopsiidae.

Bollia accentuata Henningsmoen, 1954*b*; p. 99, pl. 2, figs. 8-9 (Upper Ordovician, Norway); Drepanellidae, Bolliinae.

Brachycythere miocenicus Puri, 1954*a*; p. 249, text-fig. 7a-c (Miocene, Florida); Cytheridae, Brachycytherinae.

Bufina craigae Coley, 1954; p. 463, pl. 53, fig. 3 (Middle Devonian, New York); Thlipsuridae.

Bufina curti Coley, 1954, p. 463, pl. 53, fig. 2 (Middle Devonian, Ohio); Thlipsuridae.

Burlella cuppsi Coley, 1954; p. 460, pl. 53, fig. 13 (Middle Devonian, New York); Bairdiidae.

Bythocypris ambitruncata Peterson, 1954; p. 163, pl. 18, figs. 23-24 (Upper Jurassic, Montana); Bairdiidae.

Bythocypris biltmorensis Loranger, 1954*a*; p. 193, pl. 2, figs. 15-16 (Upper Devonian, Alberta, Canada); Bairdiidae.

Bythocypris howei Puri, 1954*a*; p. 226, pl. 1, figs. 14-16, text-fig. 2e-g (Miocene, Florida); Bairdiidae, Bairdiinae.

Bythocypris jurassica Peterson, 1954; p. 163, pl. 17, figs. 12-13 (Upper Jurassic, Montana and Wyoming); Bairdiidae.

Bythocypris mearnsa Loranger, 1954*a*; p. 193, pl. 2, figs. 37-38 (Upper Devonian, Alberta, Canada); Bairdiidae.

Bythocypris minuta Puri, 1954*a*; p. 226, pl. 1, fig. 13, text-fig. 2h (Miocene, Florida); Bairdiidae, Bairdiinae.

Candona hipolitensis Tressler, 1954*b*; p. 142, text-figs. 13-15 (Recent, fresh-water, Mexico).

Candona michoa Tressler, 1954*b*; p. 142, text-figs. 9-12 (Recent, fresh-water, Mexico).

Candona (Truncata) minuta Loranger, 1954b; p. 294, pl. 2, figs. 14-15; this is a synonym of *Candona truncata* Loranger, 1951.

Candona patzcuaro Tressler, 1954*b*; p. 139, text-figs. 4-8 (Recent, fresh-water, Mexico).

Candonocypris deeveyi Tressler, 1954*b*; p. 145, text-figs. 23-29 (Recent, fresh-water, Texas).

Cavellina buchanensis Krömmelbein, 1954*b*; pp. 200-201, pl. 3, figs. 44-47 (Middle Devonian, Australia).

Cavellina cavernarum Krömmelbein, 1954*b*; pp. 201-202, pl. 3, figs. 41-43 (Middle Devonian, Australia).

Cavellina rhenana Krömmelbein, 1954*a*; pp. 250-251, pl. 1, fig. 3a-d (Devonian, Germany).

Cavellina similis Krömmelbein, 1954*b*; pp. 199-200, pl. 3, figs. 48-50 (Middle Devonian, Australia).

Cavellina sulcelloides Krömmelbein, 1954*a*; pp. 251-252, pl. 1, fig. 4a-d (Devonian, Germany).

Cavellina teicherti Krömmelbein, 1954*b*; pp. 198-199, pl. 4, figs. 51-54 (Middle Devonian, Australia).

Ceratobairdia dorsospinosa Sohn, 1954*a*; pp. 6-7, pl. 1, figs. 27-32; pl. 2, figs. 17, 19 (Permian, Texas); Bairdiidae.

Chapmanites crassus Krömmelbein, 1954*b*; p. 203, pl. 5, figs. 67-69 (Middle Devonian, Australia).

Chapmanites lophotus Krömmelbein, 1954*b*; pp. 203-204, pl. 5, figs. 63-66 (Middle Devonian, Australia).

Chapmanites tectum Krömmelbein, 1954*b*; pp. 204-205, pl. 5, figs. 70-72 (Middle Devonian, Australia).

Checontonomus cophus Kesling, 1954*a*; pp. 578-579, pl. 59, figs. 1-7 (Middle Devonian, New York); Entomoconchidae, Oncotechmoninae.

Clithrocytheridea plena Schmidt, 1954; p. 90, pl. 5, figs. 7a, 8-9; pl. 6, figs. 7b, 10; pl. 8, figs. 32-35 (Upper Jurassic, Germany); Cytheridae, Cytherideinae.

Coelonella bergica Krömmelbein, 1954*a*; pp. 256-257, pl. 2, fig. 11a-d (Devonian, Germany).

Conchoprimitia eos Henningsmoen, 1954*a*; pp. 58-59, pl. 1, figs. 6-7 (Lower Ordovician, Norway); Leperditellidae, Conchoprimitiinae.

Conchoprimitia socialis vulgaris Henningsmoen, 1954*a*; new subspecies, pp. 61-64, pl. 1, figs. 8-9; pl. 2, figs. 1-6; 1 text-fig. (Lower Ordovician, Norway); Leperditellidae, Conchoprimitiinae.

Cooperia biltmorensa Loranger, 1954*a*; p. 194, pl. 2, figs. 33-34 (Upper Devonian, Alberta, Canada); Beecherellidae.

Coronakirkbya fimbriata Sohn, 1954*a*; p. 11, pl. 5, figs. 1-6 (Permian, Texas); Kirkbyidae, Kirkbyinae.

Coryellina indicata Sohn, 1954*a*; p. 19, pl. 1, figs. 8-11 (Permian, Texas); Primitiidae.

Craspedobolbina armata Henningsmoen, 1954*c*; pp. 47-48, pl. 4, figs. 1-4; pl. 8, figs. 10-11 (Silurian, Norway); Beyrichiidae.

Craspedobolbina dorsoplicata Henningsmoen, 1954*c*; pp. 48-49, pl. 4, figs. 5-8; pl. 5, figs. 1-3; pl. 8, figs. 14-15 (Silurian, Norway); Beyrichiidae.

Craspedobolbina expansinodata Henningsmoen, 1954*c*; pp. 49-50, pl. 4, figs. 9-17; pl. 8, figs. 12-13 (Silurian, Norway); Beyrichiidae.

Cypricercus tressleri Ferguson, 1954; p. 190, text-figs. 1-10 (Recent, South Carolina).

Cypridopsis musquizensis Tressler, 1954*b*; p. 147, text-figs. 39-41 (Recent, fresh-water, Texas).

Cypridopsis phantomensis Tressler, 1954*b*; p. 146, text-figs. 35-38 (Recent, fresh-water, Texas).

Cypridopsis potamis Tressler, 1954*b*; p. 147, text-figs. 45-47 (Recent, fresh-water, Texas).

Cypridopsis toyensis Tressler, 1954*b*; p. 147, text-figs. 42-44 (Recent, fresh-water, Texas).

Cythere apalachicolensis Puri, 1954*a*; p. 249, pl. 5, figs. 8-9, text-fig. 7d-g (Miocene, Florida); Cytheridae, Cytherinae.

Cythere redbayensis Puri, 1954*a*; p. 250, pl. 5, figs. 10-11, text-fig. 7h-i (Miocene, Florida); Cytheridae, Cytherinae.

Cythereis heteromorpha Peterson, 1954; pp. 174-175, pl. 19, figs. 20-24, text-fig. 2b (Upper Jurassic, Montana and Wyoming); Cytheridae.

Cytherella chipolensis Puri, 1954*a*; p. 300, pl. 17, figs. 5-6, text-fig. 14e-g (Miocene, Florida); Cytherellidae.

Cytherelloidea? lediformis Conti, 1954; p. 221, pl. 12, fig. 17 (Lower Jurassic, Italy).

Cytherelloidea recurvata Peterson, 1954; pp. 160-163, pl. 17, figs. 1-4, text-fig. 29 (Upper Jurassic, Montana and Wyoming); Cytherellidae.

Cytherelloidea valsoldensis Conti, 1954; p. 221, pl. 13, fig. 9 (Lower Jurassic, Italy).

Cytheridea (Spinosa) brevisspinosa Loranger, 1954*b*; p. 294, pl. 2, figs. 33-34; this is a synonym of *Cytheridea spinosa* Loranger, 1951.

Cytheridea ellipsoidea reducta Conti, 1954; new variety; p. 228, pl. 12, figs. 1-5 (Lower Jurassic, Italy).

Cytheromorpha laevigata Puri, 1954*a*; p. 275, pl. 6, figs. 3-4, text-fig. 11a-b (Miocene, Florida); Cytheridae, Loxoconchinae.

Cytheromorpha subminuta Puri, 1954*a*; p. 276, pl. 6, figs. 9-10, text-fig. 11i-j (Miocene, Florida); Cytheridae, Loxoconchinae.

Cytheromorpha warneri okaloosensis Puri, 1954*a*; new variety, p. 277, pl. 6, figs. 1-2, text-fig. 11c-e (Miocene, Florida); Cytheridae, Loxoconchinae.

Cytheropteron (Cytheropteron) bispinosum Schmidt, 1954; p. 85, pl. 7, figs. 19-24, text-figs. 2-3 (Upper Jurassic, Germany); Cytheridae, Loxoconchinae.

Cytheropteron (Cytheropteron) bispinosum bispinosum Schmidt, 1954; new subspecies, p. 85, pl. 7, figs. 19-22, text-figs. 2-3 (Upper Jurassic, Germany); Cytheridae, Loxoconchinae.

Cytheropteron (Cytheropteron) bispinosum crassum Schmidt, 1954; new subspecies, p. 87, pl. 7, figs. 23-24 (Upper Jurassic, Germany); Cytheridae, Loxoconchinae.

Cytheropteron choctawhatcheensis Puri, 1954*a*; p. 242, pl. 5, figs. 1-2 (Miocene, Florida); Cytheridae, Cytherurinae.

Cytheropteron coryelli Puri, 1954*a*; p. 242, pl. 4, figs. 13-15, text-fig. 6e (Miocene, Florida); Cytheridae, Cytherurinae.

Cytheropteron (Cytheropteron) decoratum Schmidt, 1954; p. 82, pl. 5, figs. 1-2; pl. 7, figs. 16-18 (Upper Jurassic, Germany); Cytheridae, Loxoconchinae.

Cytheropteron (Eocytheropteron?) lanceolata Peterson, 1954; p. 170, pl. 18, fig. 26 (Upper Jurassic, Wyoming); Cytheridae.

Cytheropteron leonensis Puri, 1954*a*; p. 242, pl. 4, figs. 11-12, text-fig. 6c-d (Miocene, Florida); Cytheridae, Cytherurinae.

Cytheropteron (Cytheropteron) purum Schmidt, 1954; p. 88, pl. 5, figs. 53-56; pl. 7, figs. 25-29; pl. 8, figs. 30-31 (Upper Jurassic, Germany); Cytheridae, Loxoconchinae.

Cytheropteron (Eocytheropteron?) scalpella Peterson, 1954; p. 170, pl. 18, fig. 25 (Upper Jurassic, Montana); Cytheridae.

Cytheropteron talquinensis Puri, 1954*a*; p. 243, pl. 5, figs. 5-7 (Miocene, Florida); Cytheridae, Cytherurinae.

Cytheropteron wardensis Puri, 1954*a*; p. 243, pl. 5, figs. 3-4, text-fig. 6a-b (Miocene, Florida); Cytheridae, Cytherurinae.

Dizygopleura alethaae Coley, 1954; pp. 462-463, pl. 53, fig. 6 (Middle Devonian, Ohio); Kloedenellidae.

Dizygopleura compsa Kesling, 1954*b*; pp. 168-172, pl. 1, figs. 1-26; pl. 2, figs. 13-24 (Middle Devonian, Ohio); Kloedenellidae.

Endolophia chariessa Kesling, 1954*b*; pp. 176-178, pl. 2, figs. 1-4; pl. 3, figs. 1-14 (Middle Devonian, Ohio); Barychilinidae.

Entocythere occidentalis Kozloff and Whitman, 1954; pp. 160-162, text-figs. 1-13 (Recent, fresh-water, Oregon) (commensal on the crayfish *Pacifastacus*).

Entomozoe (Nehdentomis?) acuta Rabien, 1954; p. 101, pl. 3, fig. 32 (Upper Devonian, Germany); Entomozoidae, Entomozoinae.

Eucythere triangulata Puri, 1954*a*; p. 300, pl. 16, figs. 7-8, text-fig. 13j (Miocene, Florida); Cytheridae, Eucytherinae.

Eucytherura reticulata Peterson, 1954; p. 169, pl. 18, fig. 19, text-fig. 2h-j (Upper Jurassic, Wyoming); Cytheridae.

Eucytherura weingeisti Puri, 1954*a*; p. 246, pl. 4, fig. 8, text-fig. 6k-l (Miocene, Florida); Cytheridae, Cytherurinae.

Eukloedenella biconcava Krömmelbein, 1954*b*; p. 211, pl. 2, figs. 35-36 (Middle Devonian?, Australia).

Eukloedenella ellipselloides Krömmelbein, 1954*b*; pp. 209-210, pl. 2, figs. 28-31 (Middle Devonian?, Australia).

Eukloedenella subquadrata Krömmelbein, 1954*b*; p. 210, pl. 2, figs. 32-34 (Middle Devonian?, Australia).

Exophthalmocythere? gigantea Schmidt, 1954; p. 96, pl. 6, figs. 13-15; pl. 8, figs. 40-43 (Upper Jurassic, Germany); Cytheridae, Cytherinae.

Franklinella multicostata Rabien, 1954; p. 60, pl. 3, figs. 22-23 (Upper Devonian, Germany); Entomozoidae, Entomozoinae.

Franklinella triangulata Rabien, 1954; p. 58, pl. 1, fig. 5; pl. 3, fig. 21 (Upper Devonian, Germany); Entomozoidae, Entomozoinae.

Geisina victoriana Krömmelbein, 1954*b*; pp. 212-213, pl. 1, figs. 12-15 (Middle Devonian?, Australia).

Hermania reticulata Puri, 1954*a*; p. 267, p. 11, figs. 8-9, text-fig. 9g-h (Miocene, Florida); Cytheridae, Hemicytherinae.

Herpetocypris pattersoni Tressler, 1954*b*; p. 145, text-figs. 30-34 (Recent, fresh-water, Texas).

Hollinella variopapillata Kesling, 1954*b*; pp. 179-180, pl. 3, figs. 17-19 (Middle Devonian, Ohio); Hollinidae.

Janetina beaumontensa Loranger, 1954*a*; pp. 199-200, pl. 2, figs. 17-18 (Upper Devonian, Alberta, Canada); Quasillitidae.

Jenningsina paffrathensis Krömmelbein, 1954*a*; pp. 255-256, pl. 2, fig. 10a-d (Devonian, Germany).

Kangarina chipolensis Puri, 1954*a*; p. 246, pl. 4, fig. 10, text-fig. 6g (Miocene, Florida); Cytheridae, Cytherurinae.

Kangarina howei Puri, 1954*a*; p. 246, pl. 4, fig. 7, text-fig. 6i-j (Miocene, Florida); Cytheridae, Cytherurinae.

Kangarina jacksonbluffensis Puri, 1954*a*; p. 247, pl. 4, figs. 5-6, text-fig. 6h (Miocene, Florida); Cytheridae, Cytherurinae.

Kindlella centrinoda Sohn, 1954*a*; p. 17, pl. 5, figs. 14-17 (Permian, Texas); Kirkbyidae, Kellettininae.

Kindlella fissiloba Sohn, 1954*a*; pp. 16-17, pl. 2, fig. 12; pl. 3, figs. 22-27; pl. 4, fig. 13 (Permian, Texas); Kirkbyidae, Kellettininae.

Kirkbya biltmorensa Loranger, 1954*a*; p. 198, pl. 1, figs. 27-28 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Kirkbya egremontensa Loranger, 1954*a*; p. 198, pl. 1, figs. 27-28 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Kirkbyina fragum Krömmelbein, 1954*b*; pp. 213-224, pl. 1, figs. 16-18 (Middle Devonian, Australia).

Kloedenella duvernaia Loranger, 1954*a*; pp. 201-202, pl. 1, figs. 37-38 (Upper Devonian, Alberta, Canada); Zygobolbidae, Kloedeniinae.

Kloedenella indistincta Krömmelbein, 1954*b*; pp. 208-209, pl. 2, figs. 25-27 (Middle Devonian, Australia).

Kloedenella waratahensis Krömmelbein, 1954*b*; p. 207, pl. 2, figs. 22-24 (Middle Devonian?, Australia).

Kloedenia kinsella Loranger, 1954*a*; p. 202, pl. 1, figs. 5-6; pl. 2, figs. 7-8 (Upper Devonian, Alberta, Canada); Zygobolbidae, Kloedeniinae.

Knightina? cuestaforma Sohn, 1954*a*; p. 12, pl. 2, figs. 5, 11, 14-16, 18; pl. 3, figs. 28-33 (Permian, Texas); Kirkbyidae, Kirkbyinae.

Knightina? macknighti Sohn, 1954*a*; pp. 11-12, pl. 2, figs. 7-8; pl. 3, figs. 4-12 (Permian, Texas); Kirkbyidae, Kirkbyinae.

Laccochilina tarda Henningsmoen, 1954*b*; p. 92, pl. 6, figs. 8-9 (Upper Ordovician, Norway); Eurychilinidae, Eurychilininae.

Loxoconcha alumbluffensis Puri, 1954*a*; p. 270, pl. 10, fig. 3, text-fig. 10k (Miocene, Florida); Cytheridae, Loxoconchinae.

Loxoconcha anderseni Puri, 1954*a*; p. 269, pl. 10, fig. 4, text-fig. 10c (Miocene, Florida); Cytheridae, Loxoconchinae.

Loxoconcha caudata Puri, 1954*a*; p. 270, pl. 10, fig. 9, text-fig. 10g (Miocene, Florida); Cytheridae, Loxoconchinae.

Loxoconcha chipolensis Puri, 1954*a*; p. 270, pl. 10, fig. 12, text-fig. 10f (Miocene, Florida); Cytheridae, Loxoconchinae.

Loxoconcha doryandae Puri, 1954*a*; p. 271, pl. 10, figs. 5-6, text-fig. 10d (Miocene, Florida); Cytheridae, Loxoconchinae.

Loxoconcha hendryi Puri, 1954*a*; p. 271, pl. 10, figs. 10-11, text-fig. 10i-j (Miocene, Florida); Cytheridae, Loxoconchinae.

Loxoconcha wilberti Puri, 1954*a*; p. 274, pl. 10, figs. 1-2, text-fig. 10a-b (Miocene, Florida); Cytheridae, Loxoconchinae.

Luvula howei Puri, 1954*a*; p. 293, pl. 15, fig. 11, text-fig. 13b (Miocene, Florida); Cytheridae, Bythocytherinae.

Luvula moccasinensis Puri, 1954*a*; p. 294, pl. 15, fig. 13, text-fig. 13c-d (Miocene, Florida); Cytheridae, Bythocytherinae.

Macrocypris albertensis Loranger, 1954*a*; pp. 193-194, pl. 1, figs. 19-20 (Upper Devonian, Alberta, Canada); Bairdiidae.

Macrocypris gigantea Conti, 1954; p. 227, pl. 13, figs. 1-2 (Lower Jurassic, Italy).

Macrocypris luganensis Conti, 1954; p. 226, pl. 12, figs. 18-19 (Lower Jurassic, Italy).

Macrocypris mucronata Conti, 1954; p. 227, pl. 13, fig. 5 (Lower Jurassic, Italy).

Macrocypris uniformis Conti, 1954; p. 226, pl. 13, figs. 3-4 (Lower Jurassic, Italy).

Macrodentina calcarata Triebel, 1954*a*; pp. 12-13, pl. 2, figs. 11-13; pl. 3, figs. 15-18 (Upper Jurassic, Germany); Cytheridae, Progonocytherinae.

Macronotella biltmorensa Loranger, 1954*a*; p. 198, pl. 1, figs. 27-28 (Upper Devonian, Alberta, Canada); Kirkbyidae.

Mastigobolbina socialis Krömmelbein, 1954*b*; pp. 224-225, pl. 3, figs. 38-39 (Middle Devonian?, Australia).

Menoeidina scopeli Coley, 1954; p. 462, pl. 53, figs. 10-11 (Middle Devonian, Ontario); Cytherellidae.

Microcythere stephensoni Puri, 1954*a*; p. 291, pl. 16, figs. 11-12, text-fig. 12g-h (Miocene, Florida); Cytheridae, Microcytherinae.

Microcythere striata Puri, 1954*a*; p. 291, pl. 17, figs. 9-10, text-fig. 12i-j (Miocene, Florida); Cytheridae, Microcytherinae.

Monoceratella bos Henningsmoen, 1954*b*; p. 102, pl. 6, figs. 3-4 (Upper Ordovician, Norway); Acronotellidae.

Monoceratina albertensa Loranger, 1954*a*; p. 192, pl. 2, figs. 35-36 (Upper Devonian, Alberta, Canada); Acronotellidae.

Monoceratina bifurcata Puri, 1954*a*; p. 295, pl. 15, figs. 6-10, text-fig. 12k-m (Miocene, Florida); Cytheridae, Bythocytherinae.

Monoceratina incisa Peterson, 1954*a*; pp. 164-165, pl. 17, figs. 16-17 (Upper Jurassic, Montana and Wyoming); Cytheridae.

Monoceratina pararossae Peterson, 1954; p. 165, pl. 17, figs. 21-24 (Upper Jurassic, Montana and Wyoming); Cytheridae.

Monoceratina saxonica Schmidt, 1954; p. 94, pl. 6, figs. 11-12; pl. 8, figs. 36-39 (Upper Jurassic, Germany); Cytheridae, Bythocytherinae.

Oncotechmonus chemotus Kesling, 1954*a*; pp. 577-578, pl. 59, figs. 8-21, text-fig. 1 (Middle Devonian, New York); Entomoconchidae, Oncotechmoninae.

Öpikium porkuniensis Henningsmoen, 1954*b*; pp. 82-83, pl. 2, fig. 4 (Upper Ordovician, Norway and Esthonia); Tetradellidae, Piretellinae.

Orthonotacythere dorsoconvexa Peterson, 1954; p. 164, pl. 17, figs. 9-11 (Upper Jurassic, Montana); Cytheridae.

Paracypris chipolensis Puri, 1954*a*; p. 227, pl. 1, fig. 9, text-fig. 2c (Miocene, Florida); Cypridae.

Paracypris choctawhatcheensis Puri, 1954*a*; p. 227, pl. 1, figs. 10-12, text-fig. 2a-d (Miocene, Florida); Cypridae.

Paracypris projecta Peterson, 1954; pp. 163-164, pl. 17, figs. 14-15 (Upper Jurassic, Montana and Wyoming); Cypridae.

Paracytheridea polyornata Peterson 1954; pp. 169-170, pl. 18, figs. 20-21 (Upper Jurassic, Montana); Cytheridae.

Paracytheridea shoalriverensis Puri, 1954*a*; p. 237, pl. 3, figs. 8-9, text-fig. 5g-i (Miocene, Florida); Cytheridae, Cytherideinae.

Paracytheridea washingtonensis Puri, 1954*a*; p. 240, pl. 3, figs. 10-11, text-fig. 5d-f (Miocene, Florida); Cytheridae, Cytherideinae.

Paradoxostoma(?) delicata Puri, 1954*a*; p. 288, pl. 15, fig. 3, text-fig. 12f (Miocene, Florida); Cytheridae, Paradoxostominae.

Paradoxostoma elongata Puri, 1954*a*; p. 288, pl. 15, fig. 2, text-fig. 12c (Miocene, Florida); Cytheridae, Paradoxostominae.

Paradoxostoma robusta Puri, 1954*a*; p. 289, pl. 15, fig. 1, text-fig. 12d-e (Miocene, Florida); Cytheridae, Paradoxostominae.

Payenborchella (Neomonoceratina) koenigswaldi Key, 1954*a*; pp. 359-361, pl. 3, figs. 14-18 (Recent, marine, Philippines).

Pellucistoma tumida Puri, 1954*a*; p. 290, pl. 15, fig. 5, text-fig. 12b (Miocene, Florida); Cytheridae, Paradoxostominae.

Phlyctiscapha apleta Kesling, 1954*d*; pp. 188-190, pl. 1, figs. 1-15 (Middle Devonian, Michigan); Beyrichiidae.

Plagionephrodes albertensus Loranger, 1954*a*; p. 200, pl. 1, figs. 11-12 (Upper Devonian, Alberta, Canada); Thlipsuridae.

Plagionephrodes biltmorensus Loranger, 1954*a*; p. 200, pl. 1, figs. 31-32; pl. 2, figs. 19-20 (Upper Devonian, Alberta, Canada); Thlipsuridae.

Plagionephrodes kinsellus Loranger, 1954*a*; p. 201, pl. 1, figs. 1-2 (Upper Devonian, Alberta, Canada); Thlipsuridae.

Plagionephrodes spinosus Loranger, 1954*a*; p. 201, pl. 1, figs. 35-36 (Upper Devonian, Alberta, Canada); Thlipsuridae.

Platybolbina? bulbosa Henningsmoen, 1954*c*; pp. 54-55, pl. 5, figs. 16-21; pl. 8, fig. 23 (Silurian, Norway); Primitiidae, Eurychilininae.

Platybolbina lunulifera Henningsmoen, 1954*c*; p. 53, pl. 6, figs. 1-4; pl. 8, fig. 22 (Silurian, Norway); Primitiidae, Eurychilininae.

Platybolbina tiara Henningsmoen, 1954*b*; pp. 89-91, pl. 4, figs. 4-9 (Upper Ordovician, Norway); Eurychilinidae, Eurychilininae.

Platybolbina tiara densistriata Henningsmoen, 1954*c*; new subspecies, p. 53, pl. 5, figs. 14-15; pl. 8, fig. 21 (Silurian, Norway); Primitiidae, Eurychilininae.

Polytylites digitatus Sohn, 1954*a*; p. 14, pl. 3, figs. 34-36 (Permian, Texas); Kirkbyidae, Amphissitinae.

Polyzygia (new subgenus?) *beckmanni* Krömmelbein, 1954*a*; pp. 253-255, pl. 2, figs. 7a-b, 8a-c, 9 (Devonian, Germany).

Pontocypris bolgiensis Conti, 1954; p. 223, pl. 13, fig. 6 (Lower Jurassic, Italy).

Primitia osloensis Henningsmoen, 1954*b*; pp. 83-84, pl. 1, figs. 6-7 (Upper Ordovician, Norway); Primitiidae.

Primitiella bipunctata Henningsmoen, 1954*c*; pp. 56-57, pl. 6, figs. 7-8, 11; pl. 8, fig. 19 (Silurian, Norway); Primitiidae, Euprimitiinae.

Primitiopsis dorsoplicata Henningsmoen, 1954*c*; p. 61, pl. 6, figs. 13-15; pl. 8, fig. 29 (Silurian, Norway); Primitiopsiidae.

Procytheridea crassa Peterson, 1954; pp. 172-174, pl. 19, figs. 1-5 (Upper Jurassic, Montana and Wyoming); Cytheridae.

Procytheridea exempla Peterson, 1954, pp. 171-172, pl. 19, figs. 6-14, text-fig. 2e-f (Upper Jurassic, Montana and Wyoming); Cytheridae.

Procytheridea minuta Peterson, 1954; p. 174, pl. 19, figs. 15-19 (Upper Jurassic, Montana); Cytheridae.

Progonocythere anoda Peterson, 1954; p. 166, pl. 18, figs. 1-2, text-fig. 2a (Upper Jurassic, Montana); Cytheridae.

Protobuntonia numidica Grékoff, 1954*a*; p. 490, text-fig. 1 (Upper Cretaceous, lower Senonian, Algeria); Trachyleberidae.

Protocythere pyriforma Peterson, 1954; p. 166, pl. 18, figs. 6-9 (Upper Jurassic, Wyoming and South Dakota); Cytheridae.

Pseudulrichia norvegica Henningsmoen, 1954*b*; p. 100, pl. 6, figs. 6-7 (Upper Ordovician, Norway); Drepanellidae, Bolliinae.

Richterina (Volkina) latecostata Rabien, 1954; p. 113, pl. 4, figs. 35-36 (Upper Devonian, Germany); Entomozoidae, Entomozoinae.

Richterina lisburnensa Loranger, 1954*a*; p. 196, pl. 1, figs. 23-24 (Upper Devonian, Alberta, Canada); Entomidae.

Roundyella dorsopapillosa Sohn, 1954*a*; p. 19, pl. 1, figs. 20-26; pl. 4, figs. 14, 22 (Permian, Texas); family uncertain.

Sanniolus signoides Sohn, 1954*a*; p. 18, pl. 5, figs. 9-13 (Permian, Texas); Miltonellidae.

Schmidtella subfabiformis Krömmelbein, 1954*b*; pp. 197-198, pl. 1, figs. 10-11 (Middle Devonian, Australia).

Semipetasus signatus Sohn, 1954*a*; p. 16, pl. 4, fig. 12; pl. 5, figs. 7-8 (Permian, Texas); Kirkbyidae, Kellettininae.

Signetopsis malornata Henningsmoen, 1954*c*; pp. 64-65, pl. 7, figs. 17-22; pl. 8, fig. 27 (Silurian, Norway); Primitiopsiidae.

Signetopsis quadrilobata Henningsmoen, 1954*c*; pp. 62-63, pl. 7, figs. 1-9; pl. 8, fig. 25 (Silurian, Norway); Primitiopsiidae.

Strepulites tischleri Coley, 1954; p. 463, pl. 53, figs. 7-9 (Middle Devonian, New York); Thlipsuridae.

Sulcella australis Krömmelbein, 1954*b*; p. 206, pl. 2, figs. 19-21 (Middle Devonian, Australia).

Sulcella refrathensis Krömmelbein, 1954*a*; pp. 252-253, pl. 1, fig. 5a-d (Devonian, Germany).

Terquemia hettangiana Conti, 1954; p. 220, pl. 12, fig. 12 (Lower Jurassic, Italy).

Terquemia isosceles Conti, 1954; p. 219, pl. 12, fig. 11 (Lower Jurassic, Italy).

Terquemia vanveeni Conti, 1954; p. 220, pl. 12, fig. 13 (Lower Jurassic, Italy).

Tricornina gracilis Rabien, 1954; p. 162, pl. 2, fig. 19; pl. 5, fig. 45a-c (Upper Devonian, Germany); Primitiidae, Primitiinae.

Trypetera barathrota Kesling, 1954*b*; pp. 178-179, pl. 2, figs. 8-12; pl. 3, figs. 15-16 (Middle Devonian, Ohio); Barychilinidae.

Waldeckella? turbinea Rabien, 1954; p. 154, pl. 2, figs. 17-18 (Upper Devonian, Germany); family uncertain.

Xestoleberis choctawhatcheenis Puri 1954*a*; p. 297, pl. 16, fig. 6, text-fig. 13f-g (Miocene, Florida); Cytheridae, Xestoleberinae.

Xestoleberis miocenicus Puri, 1954*a*; p. 298, pl. 16, fig. 5, text-fig. 13e (Miocene, Florida); Cytheridae, Xestoleberinae.

Xestoleberis triangularis Puri, 1954*a*; p. 298, pl. 16, figs. 1-4, text-fig. 13h-i (Miocene, Florida); Cytheridae, Xestoleberinae.

NEW NAMES IN 1954

Murrayina howei Puri, 1954*a*; p. 255; new name for *Cythere producta* Ulrich and Bassler, 1904 (non Brady, 1866).

FORMS WITH NOMENCLATURA APERTA IN 1954

Amphizona sp. cf. *A. asceta* Kesling and Copeland, 1954; p. 159, pl. 2, figs. 5-7 (Middle Devonian, New York); Kirkbyidae.

Argilloecia sp., Key, 1954*b*; p. 218, pl. 3, fig. 8a-b; pl. 6, fig. 1 (Recent, South America); Cypridae.

Bairdia sp. A, Krömmelbein, 1954*b*; p. 206, pl. 4, fig. 61 (Middle Devonian, Australia).

Bairdia sp. B, Krömmelbein, 1954*b*; p. 206, pl. 4, fig. 62 (Middle Devonian?, Australia).

Bairdiocypris sp. A, Krömmelbein, 1954*b*; p. 205, fig. 73 (Middle Devonian, Australia).

Bradleya sp., Key, 1954*b*; p. 223, pl. 4, fig. 13a-c; pl. 6, fig. 10 (Recent, South America); Cytheridae, Cytherinae.

Cavellina teicherti subsp. A, Krömmelbein, 1954*b*; p. 199, pl. 4, figs. 55-57 (Middle Devonian, Australia).

Chapmanites? sp. A, Krömmelbein, 1954*b*; p. 205, pl. 4, figs. 58-60 (Middle Devonian, Australia).

Cytherois? sp., Key, 1954*b*; p. 229, pl. 5, fig. 18 (Recent, South America); Cytheridae, Paradoxostominae.

Cytheropteron sp. A, Key, 1954*b*; p. 226, pl. 5, fig. 6 (Recent, South America); Cytheridae, Loxoconchinae.

Cytheropteron sp. B, Key, 1954*b*; p. 226, pl. 5, fig. 7 (Recent, South America); Cytheridae, Loxoconchinae.

Cytherura sp., Key, 1954*a*; p. 358, pl. 3, fig. 6 (Recent, marine, Philippines).

Cytherura sp., Key, 1954*b*; p. 227, pl. 5, fig 11 (Recent, South America); Cytheridae, Cytherurinae.

Dibolbina sp. A, Krömmelbein, 1954*b*; p. 225, pl. 3, fig. 37 (Middle Devonian?, Australia).

Drepanella? sp. A, Krömmelbein, 1954*b*; p. 225, pl. 3, fig. 40 (Middle Devonian, Australia).

Drepanellina? sp. A, Krömmelbein, 1954*a*; p. 256, pl. 1, fig. 6 (Devonian, Germany).

Eukloedenella sp. A, Krömmelbein, 1954*b*; pp. 211-212, pl. 5, figs. 74-75 (Middle Devonian?, Australia).

Eukloedenella sp. B, Krömmelbein, 1954*b*; p. 212, pl. 5, figs. 76-77 (Middle Devonian?, Australia).

Kirkbya sp., Sohn, 1954*a*; p. 10, pl. 2, figs. 4, 9; pl. 3, figs. 1-3 (Permian, Texas); Kirkbyidae, Kirkbyinae.

Kloedenella sp., Loranger, 1954*a*; p. 202, pl. 1, figs. 25-26 (Upper Devonian, Alberta, Canada); Zygobolbidae, Kloedeniinae.

Leptocythere sp., Key, 1954*a*; p. 354, pl. 1, fig. 10 (Recent, marine, Phillippines).

Octonaria sp., Kesling, 1954*b*; p. 181, pl. 2, fig. 7 (Middle Devonian, Ohio); Thlipsuridae.

Paracytheretta sp., Key, 1954*b*; p. 221, pl. 4, fig. 7; pl. 6, fig. 7a-b (Recent, South America); Cytheridae, Cytherinae.

Paradoxostoma sp., Key, 1954*a*; p. 362, pl. 3, fig. 9 (Recent, marine, Philippines).

Richterina (Maternella?*)* sp. A, Rabien, 1954; p. 149, pl. 5, fig. 43 (Upper Devonian, Germany); Entomozoidae, Entomozoinae.

Roundyella? sp. A, Krömmelbein, 1954*a*; p. 256, pl. 2, fig. 12 (Devonian, Germany).

Quadracythere? sp., Key, 1954*a*; p. 358, pl. 2, fig. 11 (Recent, marine, Philippines).

Sigmobolbina? sp., Henningsmoen, 1954*b*; p. 77, pl. 1, figs. 1-2, text-fig. 1 (Upper Ordovician, Norway); Sigmoopsiidae.

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SUPPLEMENT TO NEW SUBGENERA, GENERA AND SUPRAGENERIC CATEGORIES IN 1950-1953

BEYRICHIIDA Pokorný, 1953, new order under Class Ostracoda; pp. 221, 227, 230.

LEPERDITIIDA Pokorný, 1953, new order under Class Ostracoda; pp. 222, 227, 231.

MYODOCOPIDA Pokorný, 1953, new order under Class Ostracoda; pp. 222, 227, 231.

PODOCOPIDA Pokorný, 1953, new order under Class Ostracoda; pp. 221, 227, 231.

Allostracites Přibyl, 1953, new name for *Paracythere* Ulrich and Bassler, 1932 (non Müller, 1894); p. 341.

Callistocythere Ruggieri, 1953, new subgenus of *Leptocythere; Cythere littoralis* Müller, 1894; p. 99 (Recent, Europe); Pliocene to Recent, marine.

Glossomorphites Hessland, 1953, new name for *Glossopsis* Hessland, 1949 (non Bush, 1904); p. 227.

Kozłowskiella Přibyl, 1953, new subgenus of *Ulrichia; Ulrichia (Kozłowskiella) kozłowskii* Přibyl, 1953; p. 316, pl. 1, figs. 1-18, text-fig. 1 (Middle Devonian, Poland); Middle Devonian, marine, Drepanellidae, Bolliinae.

Savagellites Přibyl, 1953, new name for *Savagella* Geis, 1932 (non Foerste, 1920); p. 341.

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In Zaspelova (1953), the following ostracode genera and species are mentioned; however, the original references are as yet unknown to me: *Milanovskya ventrocristata*, p. 281; *M. bicornis* Gleb. and Zasp., p. 282; *Tulenia(?) ovata* Zasp., p. 281; *Mennerella schelonica* Gleb. and Zasp., p. 282; *Kloedenellitina sigmaeformis* (Batalina), p. 282; *Indivisia latiformia* Zasp., p. 282; *Uchtovia elongata* (Gleb. and Zasp.), p. 282; *Ellesmerina incognita* Gleb. and Zasp., p. 282; *Buregia bispinosa* Zasp., p. 282.

SUPPLEMENT TO NEW SPECIES AND SUBSPECIES IN 1953

Bradleya kaiata Hornibrook, 1953*c*; pp. 309-310, text-fig. 2, fig. 6 (Upper Eocene, New Zealand).

Bufina europaea Přibyl, 1953; p. 333, pl. 4, figs. 1-5 (Middle Devonian, Poland); Thlipsuridae, Ropolonellinae.

Bythocythere ferox Hornibrook, 1953*c*; p. 307, text-fig. 2, fig. 1 (Upper Eocene to Upper Pliocene, New Zealand).

Caudites impostor Hornibrook, 1953*c*; p. 311, text-fig. 2, figs. 3-5 (Lower Eocene, New Zealand).

Cypridopsis meruensis Lindroth, 1953; p. 98, text-figs. 88-92 (Recent, Africa); Cyprinae.

Cyprinotus humilis Lindroth, 1953; p. 62, text-figs. 14-23 (Recent, Africa); Cyprinae.

Cyprinotus intermedius Lindroth, 1953; p. 70, text-figs. 34-45 (Recent, Africa); Cyprinae.

Cyprinotus kliei Lindroth, 1953; p. 66, text-figs. 24-33 (Recent, Africa); Cyprinae.

Cyprinotus nonstriatus Lindroth, 1953; p. 73, text-figs. 46-50 (Recent, Africa); Cyprinae.

Cytheralison amiesi Hornibrook, 1953*c*; pp. 306-307, text-fig. 1, figs. 9-10 (Lower Oligocene, New Zealand).

Cythereis semicontigua Hornibrook, 1953*c*; pp. 307-309, text-fig. 2, fig. 9 (Lower Eocene(?), Middle Eocene to Lower Oligocene, New Zealand).

Cytheridea (Clithrocytheridea) marwicki Hornibrook, 1953*c;* p. 305, text-fig. 1, figs. 2, 3, 8 (Upper Oligocene, New Zealand).

Cytherideis complicata Ruggieri, 1953; p. 109, pl. 4, figs. 34-35 (Pliocene to Recent, Europe).

Cytherura incongruens perinflata Ruggieri, 1953, new subspecies; p. 118, pl. 4, figs. 38, 38a (Pliocene to Recent, Europe).

Eucypris kenyensis Lindroth, 1953; p. 53, text-figs. 1-6 (Recent, Africa); Cyprinae.

Eucypris montana Lindroth, 1953; p. 56, text-figs. 7-13 (Recent, Africa); Cyprinae.

Euglyphella(?) polonica Přibyl, 1953; p. 334, pl. 4, figs. 6-9 (Middle Devonian, Poland); Thlipsuridae, Ropolonellinae.

Glyptopleura mesodevonica Přibyl, 1953; p. 328, pl. 6, figs. 14-15 (Middle Devonian, Poland); Glyptopleuridae.

Hemicythere parvitenuis Hornibrook, 1953*c*; p. 310, text-fig. 1, fig. 7 (Upper Eocene, New Zealand).

Hemicythere speyeri nevianii Ruggieri, 1953, new subspecies; p. 89, pl. 1, figs. 7, 7a; pl. 3, figs. 18, 18a, 19, 19a (Recent, Atlantic Ocean).

Leperditia fulva Howell, 1953; p. 7, pl. 2, figs. 1-6 (Lower Ordovician, Arkansas); Leperditiidae.

Leptocythere kaiata Hornibrook, 1953*c;* p. 306, text-fig. 1, fig. 5 (Upper Eocene, New Zealand).

Limnocythere africana minor Lindroth, 1953, new subspecies; p. 115, text-figs. 113-115 (Recent, Africa); Limnocytherinae.

Macrocypris eocuneata Hornibrook, 1953*c*; pp. 303-305, text-fig. 1, fig. 6 (Lower Eocene to Lower Oligocene, New Zealand).

Poloniella kielanae Přibyl, 1953; p. 325, pl. 6, figs. 6-13, text-fig. 3 (Middle Devonian, Poland); Kloedenellidae.

Loxoconcha diademata Ruggieri, 1953; p. 111, pl. 4, figs. 29, 29a, 30-32; pl. 6, figs. 53-54 (Pleistocene to Recent, Europe).

Protocythere hayi Hornibrook, 1953*c*; pp. 305-306, text-fig. 1, figs. 1, 4 (Middle to Upper Eocene, New Zealand).

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Stenocypris decipiens anomala Lindroth, 1953, new subspecies; p. 78, text-figs. 53-57 (Recent, Africa); Cyprinae.

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SUPPLEMENT TO FORMS WITH NOMENCLATURA APERTA IN 1953

Coryellites(?) n. sp., Přibyl, 1953; p. 337, pl. 7, figs. 11-12 (Middle Devonian, Poland); Bairdiidae.

Cypridopsis sp., Lindroth, 1953; p. 101, text-fig. 93 (Recent, Africa); Cyprinae.

Pontocypris sp., Ruggieri, 1953; p. 129, pl. 2, fig. 16 (Pliocene, Europe).

CORRECTION OF BIBLIOGRAPHY FOR 1953

In Levinson (1955, Micropaleontology, vol. 1, no. 3, p. 286), the entry "Staub, E. W., 1950" should read "Staub, E. W., 1952."

notes and comment

Lagena-x again

J. H. VAN VOORTHUYSEN
Geologische Dienst
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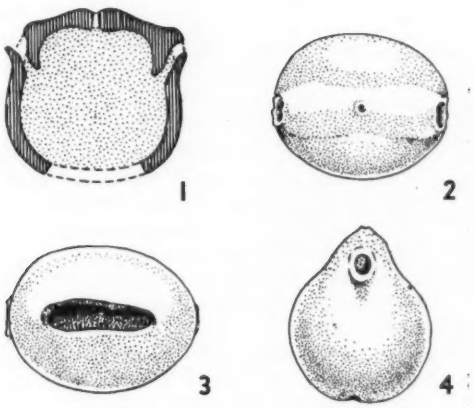

TEXT-FIGURES 1-4

CROSS SECTION AND THREE EXTERNAL VIEWS OF LAGENA-X

In our Oligocene greensands we have found some specimens of another "species" of the problematic fossil *Lagena*-x, which we are illustrating here. It has the same dimensions as the Pliocene form (Voorthuysen, 1949, 1953).

Professor R. C. Moore of the University of Kansas, who, together with Dr. Lalicker and Dr. Fisher, studied thin sections of the Pliocene *Lagena*-x was unable to determine its taxonomic position. Professor Moore and his colleagues, however, at least established that it is not an echinoderm fragment.

Mr. Jaime Martins Ferreira and Mr. Arménio Tavarez Rocha of Lisbon have informed the writer that they have found *Lagena*-x in Upper Miocene(?) samples from Portugal, which indicates that the problematic fossil is not endemic.

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On the age of the Choffatella-bearing beds in Venezuela

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Venezuelan Atlantic Refining Company
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As pointed out in the writer's recent paper entitled "On some erroneous or questionable determinations of *Choffatella*" (Maync, 1955), *Choffatella decipiens* Schlumberger is known to occur in Colombia stratigraphically below the *Pulchellia-Nicklesia* beds of Barremian-Hauterivian age (Petters, 1954). Accordingly, the *Choffatella decipiens* zone of Colombia certainly extends downward into the Barremian-Hauterivian.

A fauna containing, among others, the ammonite genera *Pulchellia, Karstenia, ?Nicklesia,* etc., was recently discovered in the Toco area, Northern Range of Trinidad, B.W.I. (Kugler, 1953). This fauna is dated as Barremian (Imlay, 1954). Through the courtesy of Drs. H. G. Kugler and H. Bolli, Trinidad Leaseholds Limited, the writer was recently enabled to identify numerous specimens of *Choffatella decipiens* in these Toco beds. Both in Colombia and Trinidad, *Choffatella decipiens* thus appears in beds of Barremian-Hauterivian and Barremian age, respectively, and it is reasonable to assume the same age for the lowermost occurrence of this form in the Apón and Barranquin formations of Venezuela, hitherto believed to be basal Aptian (Rod and Maync, 1954).

In a recent paper (Von Der Osten, 1955), the conclusion was drawn that the Barranquin formation of western Sucre (eastern Venezuela) is largely of marine origin, corresponds in its entirety to the middle Aptian, and does not extend into the Barremian or Neocomian. This age determination is based on the occurrence of fossils in the Morro Blanco member, which is placed at least 1000 meters below the top of the formation.

Von Der Osten's perplexing statement (1955, p. 132) that the writer has accepted his conclusions with regard to the above is not quite in accordance with the facts. It was repeatedly pointed out that the Barranquin section, measured by Von Der Osten as a normal stratigraphic sequence, might be transected by faults and thrusts. Accordingly, it might be argued whether the Morro Blanco member actually represents a stratigraphic unit within the middle-lower part of the Barranquin formation. The listed fossils, mainly corals and pelecypods, are, however, of only slight stratigraphic value, as they are not indicative of a certain stage within the Lower Cretaceous but range from the Hauterivian into the upper Albian. The presence of *Choffatella decipiens,* ascertained by the writer in the Morro Blanco limestone, no longer can be taken as evidence of an Aptian age, since this foraminiferan, both in Colombia and Trinidad, appears in a horizon of positively pre-Aptian age. As pointed out above, the writer is inclined to believe, contrary to Von Der Osten, that the lowermost Cretaceous formations of Venezuela are pre-Aptian in age, as in Colombia and Trinidad.

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news reports

BENELUX

J. H. VAN VOORTHUYSEN

BELGIUM

Your correspondent is very glad to be able to report that micropaleontological activity in Belgium is increasing to a large extent.

University of Louvain, Coal Museum

L'abbé J. Goreux is continuing his study of the Givetian ostracodes of Belgium. Dom Remacle Rome, O.S.B., director of the Paleontological Museum of the University of Louvain, has also continued his studies of the basal Tournaisian (Carboniferous) and the Crag (Plio-Pleistocene) of Antwerp. When I visited Father Rome this summer, he showed me something of his work, which has been in progress during more than twenty years but never published. When I asked him why he hesitated to publish his results, he told me that he was never sure of his identifications. We all understand his difficulties, and of course we respect his feelings; his humility is the mark of a scientist of high standards. Nevertheless, I sincerely hope that in the near future he will publish some of his results, even though they may be preliminary. I am sure that ostracode workers all over the world will be grateful to him.

University of Louvain, Geological Institute

Dr. F. Gullentops, in collaboration with Mr. van Kepiel, is engaged in a study of a small but interesting foraminiferal fauna from the Tongrian (Lower Oligocene). The fauna represents a specialized association consisting principally of Miliolidae. He is also studying the Lagenidae of the Plio-Pleistocene of Antwerp. There are fifty to sixty different species, including *Fissurina* and *Parafissurina*.

University of Liége, Laboratory of Micropaleontology

Professor Ubaghs reports that work on Cretaceous and Tertiary deposits from the Cuanza sedimentary basin of Angola has been going on during 1955. Miocene, Oligocene, Eocene, Paleocene, and Upper Cretaceous microfaunas have been investigated. Pelagic species have been encountered in rather large numbers, allowing correlations with time- and rock-units of the international stratigraphic scale.

Royal Belgian Institute of Natural Sciences, Botanical Section, Brussels

In the "Volume Jubilaire Victor van Straelen," vol. 1, Brussels, 1954, pp. 141-147, Dr. R. Vanhoorne published an article entitled "L'oscillation d'Alleröd en Belgique." In this paper the existence of the Alleröd-layer was reported for the first time in Belgium, at Eeklo. Pollen grains of *Artemisia* sp. and *Gypsophila* sp. were identified.

An extensive treatise by F. Stockmans, R. Vanhoorne and C. van den Berghen, entitled "Étude de botanique du gisement de tourbe de la région de Pervijze (plaine maritime belge)," will soon be published. It contains a complete botanical study of a buried peat deposit extending over an area of 240 square kilometers.

Royal Belgian Institute of Natural Sciences, Paleontological Section, Brussels

Under the leadership of Dr. M. Lecompte, professor of paleontology at the University of Louvain, Dr. Jean Minnig is working on a study of the foraminifera of the Bruxellian (Middle Eocene). At the same time he is studying the microfauna of the same sediments in the Paris Basin. The results so far indicate that in the near future it will be possible to publish a more exact correlation between the French and Belgian basins during Middle Eocene time.

NETHERLANDS

University of Leyden

Professor van der Vlerk of the Geological Institute is engaged in a study of the distribution of the genus *Lepidocyclina*. A. C. van Ginkel, one of his pupils, is studying the Fusulinidae of the Carboniferous of northern Spain. Miss H. E. de Boer and A. P. Audretsch are investigating the significance of the morphology of the embryonic apparatus in the genus *Discocyclina* for systematic purposes.

University of Utrecht

Dr. C. W. Drooger, conservator of the Geological Institute, published the following papers during the past year: "*Miogypsina* in northwestern Morocco" (Proc. K. Nederl. Akad. Wetensch., vol. 57, 1954, pp. 580-591); "Remarks on the species concept in paleontology" (Micropaleontologist, vol. 8, no. 4, 1954, pp. 23-26); "The Oligocene-Miocene boundary on both sides of the Atlantic" (Geol. Mag., vol. 91, 1954, pp. 514-518); and (with J. P. H. Kaasschieter and A. J. Key) "The microfauna of the Aquitanian-Burdigalian of southwestern France" (Verh. K. Nederl. Akad. Wetensch., vol. 21, no.

2, 1955, pp. 1-136). The last is a study of the microfauna of the type localities of the Aquitanian and Burdigalian.

A. J. Key has nearly finished his study of the Eo-Oligocene ostracodes of Belgium and the revision of the Bosquet collection. It will be published in the near future. The studies of the foraminifera of the Belgian Oligocene by D. A. J. Batjes and of those of the Belgian Eocene by J. P. H. Kaasschieter are making good progress.

University of Groningen

Professor H. T. Waterbolk is now Director of the Biological-Archaeological Institute, succeeding Professor van Giffen, who retired two years ago on his seventieth birthday. Professor Waterbolk reports that, for the time being, he has little or no time to do microscopical research work. The palynologist of his Institute, W. van Zeist, graduated with a thesis entitled "Pollenanalytical investigations in the northern Netherlands." He is continuing these investigations.

University of Amsterdam

Professor H. J. MacGillavry of the Geological Institute is engaged in a study of the Miogypsinidae and other groups of larger foraminifera. He is studying in particular the orbitoids of the Maastrichtian on the basis of newly collected samples from St. Pietersberg, the type locality.

Geological Bureau of the Netherlands Coal Mining District

Dr. S. Dijkstra has published the following papers: "Une possibilité de macérer des spores carbonifères d'une psammite aux lits charboneux" (C. R. VIII. Congr. Internat. Bot., Paris, 1954); and "La correlation des veines de charbon par les mégaspores" (Publ. Assoc. Étud. Pal., no. 21, 1955).

State Museum of Natural History, Leyden

Dr. C. J. Keyzer has a paper on the Miliolidae of Cadaques Bay (Spanish Mediterranean) nearly ready for publication. He is continuing his studies of the foraminifera of the Galathea Expedition from Dakar around Africa to the Seychelles Islands.

Stratigraphic laboratory of the "N.V. de Bataafsche Petroleum Maatschappij" (Royal Dutch/Shell Group), The Hague

A number of transfers have taken place among the staff of the paleontological laboratory since my last report. T. F. Grimsdale and J. D. Emeis are still at The Hague, but R. Haak has been transferred abroad. Miss C. G. Rümke has left the B.P.M. to take up a job with the South African Geological Survey, in Pretoria. O. S. Kuyl is now with the Palynological Section, and B. L. Meyer, from the University of Munich, has joined the staff as a palynologist.

The sedimentology laboratory, formerly located in Amsterdam, has been moved to The Hague and is now functioning as a unit within the stratigraphic laboratory. L. Ritsema, J. J. C. H. Houbolt, and S. B. Spyer were attached to this section. U. Haanstra is working in the Oldenzaal (Netherlands) laboratory, replacing G. C. L. Sung, who has been transferred abroad.

The following papers have been published by members of the Shell staff: "The application of palynology to oil geology with reference to western Venezuela," by O. S. Kuyl, J. Muller, and H. T. Waterbolk (Geol. en Mijnb., new ser., vol. 17, no. 3, 1955); and "The stereoscopic polarizing microscope, a tool for the sedimentary geologist," by J. J. C. H. Houbolt (ibid., no. 9, 1955).

Geological Survey of The Netherlands, Haarlem

W. H. Zagwijn, who is now in charge of the Paleobotanical Laboratory, is working, with two assistants, on the Pliocene-Pleistocene boundary and the subdivision of the lower Pleistocene, based mainly on pollen analysis and on the study of fossil fruits and seeds. In addition, a detailed study of the Holocene in the western part of The Netherlands has been carried out for mapping purposes. One of the results of this study has been the discovery that marine tidal-flat and marsh deposits are quite suitable for pollen-analytical treatment. A study of Tertiary pollen-bearing sediments, especially those of Miocene and Paleocene age, has also been started.

The following paper has been published by members of the Geological Survey: "Over de stratigrafie van het fluviatiele Pleistoceen in West-Nederland en Noord-Brabant," by J. W. C. Doppert and J. I. S. Zonneveld (Meded. Geol. Stichting, new ser., no. 8, pp. 13-30, 1955).

Your correspondent is continuing his ecological and sedimentological study of the Eems estuary (Wadden Sea). During a trip to Italy for the purpose of gathering stratigraphic and tectonic data on the Plio-Pleistocene, we were the guest of Professor Socin in Turin, of Professor Ruggieri in Bologna, and of Miss Clelia Panseri in Rome. It was indeed a most instructive and pleasant visit. In my opinion, the Plio-Pleistocene boundary is even more difficult to establish in Italy than it is in the more northerly countries, because there was less climatic change during the colder periods.

In September of 1954, we participated in an interesting field trip to the Paris Basin, together with many European colleagues. We collected samples from the classic type localities there. The Institut Français du Pétrole was our host. In 1955, we went to Germany for the same purpose, this time as guests of the Amt für Bodenforschung in Hannover.

During 1955, we have had the pleasure of seeing the following colleagues from other countries here: Dr. Kollmann of Vienna, Dr. Fr. Schmidt of Hannover, Dr. Y. Nagappa of India, Dr. J. C. Troelsen of Copenhagen, Robert E. Dietz of Santiago, Dr. R. Lagaay of Venezuela, and Rolf W. Feyling-Hanssen of Oslo.

The laboratory of Dr. Jan Hofker, The Hague

In 1954, a short paper on the species of the genus *Streblus* in the Pliocene of Kruisshans, Belgium, was completed, as well as a longer one on Eocene foraminifera from Ecuador. Two studies, one on the foraminifera of the Bay of Naples and the other on the foraminifera of the beaches of the Antilles, were planned. Also in 1954, a long paper on the foraminifera of the Oligocene of Ecuador was almost finished when the

establishment of a commission to study the Dutch Cretaceous diverted all attention to that subject. In the meantime however, several smaller papers appeared: "Über die Familie Epistomariidae" (Palaeontographica, vol. 105); "The toothplate of *Ceratobulimina*," "The taxonomic position of *Allomorphina trigona* Reuss," and "Morphology of *Globigerinatella insueta* Cushman and Stainforth" (Contr. Cushman Found. Foram. Res., vol. 5); "Kleinforaminiferen und paläontologische Chronologie" (Neues Jahrb. Pal., 1955); and, in a series on the foraminifera of South Limburg (Netherlands), papers on *Lockhartia roestae, Pseudoparrella alata,* and *Gavelinella danica* (Natuurh. Maandbl., vol. 44). Two papers are now in press, one on West Indian foraminifera (a companion paper to the Siboga Report, Part III), and the other entitled "Die Foraminiferen der Oberkreide von Nord-West Deutschland und Holland."

Presumably, the study of the large amount of material from the Dutch Cretaceous now at hand will occupy most of Dr. Hofker's time in the near future. Two papers, one entitled "Die Globotruncaninae von Nordwestdeutschland und Holland" and the other "The foraminifera of the Vincentown formation, New Jersey," have recently gone to press. The latter paper was written when the author discovered true boreal Paleocene in the upper beds of what had previously been called the uppermost Maestrichtian of South Limburg (Netherlands). The Vincentown fauna shows a striking resemblance to the boreal lowermost Paleocene described by Brotzen in southern Sweden, and the Dutch Paleocene bears a quite similar fauna.

Studies of the Upper Cretaceous of various Belgian localities are now going on, principally in collaboration with Professor Ubaghs and Professor Calembert in Liége, in an attempt to solve certain problems concerning facies and stratigraphic relationships in the Dutch Upper Cretaceous localities. A paper on the interesting fauna of the *Pseudotextularia* zone of the Maasbühl No. I boring (Professor Wicher) has also been completed, and studies on *Globigerina* and *Streblus* are in progress.

J. H. VAN VOORTHUYSEN
Haarlem, Netherlands

COLOMBIA

VIKTOR PETTERS

Instituto Geológico Nacional

Dr. H. Buergl and his assistants have published some of the results of their studies of Miocene microfaunas in northern coastal Colombia, in a paper entitled "Micropaleontología y estratigrafía de la sección Arroyo Saco, Depto. de Atlántico," by Buergl, Barrios and Röström (Bol. Geol., vol. 3, no 1, pp. 1-114, pls. 1-9, 1955). The section discussed by Buergl and his colleagues forms a stratigraphic link between the younger section described by C. D. Redmond from another part of the same syncline ("Miocene foraminifera from the Tubará beds," Jour. Pal., vol. 27, no. 5, pp. 708-733, pls. 74-77, 1953), and another section, much farther inland, studied by R. Sarmiento and your correspondent, on which a paper is now in press for the January number of Micropaleontology ("Oligocene and Lower Miocene biostratigraphy of the Carmen-Zambrano area, Colombia"). These three sections overlap in age only slightly, Redmond's oldest samples falling somewhere within the time interval of Buergl's Saco formation, and Buergl's lower Piojó and Gallinazo formations occupying approximately the same time interval as Petters and Sarmiento's *Uvigerina subperegrina* and *Bulimina carmenensis* zones, although the two are not facies equivalents. The sections must be connected as indicated above, despite slight discrepancies between Redmond and Buergl in correlating their sections with Anderson's divisions of the Tubará group ("Marine Miocene and related deposits of north Colombia," Proc. Calif. Acad. Sci., ser. 4, vol. 18, no. 4, pp. 73-213, pls. 8-23, 1929), and despite the fact that Petters and Sarmiento (1956) place the boundary between the Lower and Middle Miocene at the point where Buergl divides his "Mioceno inferior bajo" from his "Mioceno inferior alto." Redmond's, Buergl's, and Petters and Sarmiento's papers together offer a fairly representative account of the development of the foraminiferal faunas of Caribbean Colombia from the early Oligocene to the Middle Miocene.

The palynological section of the Instituto, under the direction of Dr. van der Hammen, has completed a study of pollen and spores from the uppermost Cretaceous to the lowermost Tertiaries. Higher Tertiary floras are now being studied. The results have been published, or are in the process of publication, in the "Boletín Geológico." Evolution is held responsible for the appearance and disappearance of marker species that are used for the correlation of larger stratigraphic units. A much finer zonation, however, is obtained by means of minor variations in the pollen assemblages, variations that are attributed to climatic changes. A paper by van der Hammen entitled "Princípios para la nomenclatura palinológica sistemática" (Bol. Geol., vol. 2, no. 2, pp. 1-27, pls. 1-3, 1954) is reviewed by R. E. Malloy as follows: "In this thought-provoking publication, Dr. van der Hammen strongly and logically advocates a strict form classification divorced from any consideration of the natural affinities of each. For the most part, the specific system proposed is drawn from the morphological pollen nomenclature of Iversen and Troels-Smith ("Pollenmorphologische Definitionen und Typen," Danmarks Geol. Unders., ser. 4, vol. 3, no. 8, 1950), and employs their form-genera, with "sculpture-subgenera" where consid-

ered necessary. The system advanced appears acceptable but has one weakness, in that the shape of the pollen grains is apparently considered only at the species level, as are such other characters as shape of pores, geminate colpae, and zonate apertures. In the reviewer's opinion, the shape (whether deltoid or circular spherical) is an obvious character which should play a more important part in any classification than surface ornamentation. However, van der Hammen's system has the merit of relative simplicity while providing for the splitting of present unwieldy genera. A relatively novel idea is the suggestion to assign, as types of the proposed form-genera, the appropriate pollen of living plants with their plant names. No descriptions or figures of these modern pollen are given in this list of types, however, and of course any genus already described in the literature with its type must have this type conserved according to best taxonomic usage. Nevertheless, van der Hammen's system has the obvious advantage of making typical pollen forms more widely available and thus may eliminate much misunderstanding.

"The section on spores does not take into consideration the published work on Paleozoic pteridophyte spores and gymnosperm pre-pollen. Van der Hammen would employ three major form-genera, *Aletes, Triletes,* and *Monoletes,* with their accompanying 'sculpture-subgenera', as for the pollen. It seems quite logical to the reviewer to expect that many Mesozoic and Tertiary spore types can be included in existing genera described from Paleozoic rocks. Yet, in effect, a different classification for spores of the younger geologic systems is created. In general, the paper certainly is a worthwhile contribution to the field of plant microfossils and should provide a basis for much future discussion and constructive thinking."

Concesionária de Petróleo Shell Condor

A. Maurenbrecher is in charge of the Exploration Laboratory. At present, he is Shell's only paleozoologist, since Allan McGugan left the Company at the end of October. (Your correspondent prefers the term "paleozoologist" rather than "paleontologist," to differentiate these workers from the palynologists, who have become so numerous in recent years.) During 1955, Shell also established a pollen section in Bogotá. It is headed by D. Diederics, who comes from Shell's pollen laboratory in The Hague.

Richmond Petroleum Company

F. Amato has been transferred permanently from Peru to Bogotá as head of the paleontological laboratory.

Socony Mobil Oil Company

There are no staff changes to report since last year.

International Petroleum (Colombia) Ltd.

Ralph Biel is a welcome addition to Intercol's staff. A former student of Dr. Brooks F. Ellis at New York University, he wrote his Master's thesis on Upper Cretaceous foraminifera from Delaware. C. G. Allen, I. L. Polson, and your correspondent are the other paleozoologists here. R. Sarmiento of the pollen section is now working in Tulsa with the Carter Oil Company. He was replaced in Bogotá by Raymond E. Malloy, formerly with Carter. Malloy is assisted by R. Obando and a new trainee, H. Olaya.

VIKTOR PETTERS
International Petroleum (Colombia) Ltd.
Bogotá, Colombia

EGYPT

RUSHDI SAID

The long-awaited monograph on the Upper Eocene foraminifera of Egypt by Dr. S. E. Ansary has finally appeared in print. This excellent paper includes systematic descriptions of 112 species of foraminifera from three widely separated Upper Eocene outcrops, one in eastern Sinai, one in the Nile Valley, and one in Fayum. This well-illustrated monograph will be considered basic whenever the biostratigraphy of the Egyptian Tertiary is discussed.

In the Proceedings of the last International Geological Congress, Dr. S. E. Nakkady and Dr. A. Osman published a paper on the *Globotruncana* species encountered in two Upper Cretaceous sections in Sinai. They described several new species and demonstrated their stratigraphic value in these two sections. In another paper, Dr. Nakkady established a new genus, *Abudaragina,* for some peculiar *Eponides*-like forms with distinctive apertural characters, which he found in the early Mesozoic rocks of Abu Darag in the Eastern Desert of Egypt.

Dr. S. Omara has just come back from a visit to England and Germany, where, among other activities, he worked on some foraminifera from the Cenomanian of Sinai. He is now publishing a paper in which he emends the genus *Thomasinella* Schlumberger, showing that it is related to *Reophax.* He also describes a new genus of rotaliid foraminifera with peculiar apertural characters and a unique wall structure.

M. A. Ghorab has just come back from the United States, bringing with him a wealth of information that he has laboriously worked out during the past several years, on Upper Cretaceous faunas from numerous sections in Sinai and the Eastern Desert. All of us are waiting anxiously for the publication of this work.

The results of the work of Said and Phillip on the Pleistocene foraminifera of the Mediterranean Coast are now in press. One of the interesting conclusions presented is that the connection between the Mediterranean and the Red Sea seems to have taken place during Milazzian time, rather than during the Tyrrhenian as customarily assumed.

Said and Kenawy's monograph on the Upper Cretaceous and Lower Tertiary foraminifera of Sinai will be published in Micropaleontology. Tectonic control of the spatial distribution of foraminifera in this basin of deposition is suggested and demonstrated.

Said and Barakat are systematically describing the foraminifera of the Jurassic and Lower Cretaceous rocks of northern Sinai. A paper on the Bajocian foraminifera of Gebel Maghara is now being submitted for publication in Micropaleontology. This paper shows that, during the Bajocian, Egypt became connected with the northern European basin of deposition for the first time in its geologic history.

Said and Basiouni have finished their illustrated monograph on the Pliocene foraminifera of the Nile Valley. This paper emphasizes the zoogeography of the species and their stratigraphic value.

Among the distinguished visitors to Egypt during 1955 was Professor Cuvillier, who returned, after years of absence, to his "second home," where he was greeted heartily by numerous old friends. He gave two stimulating talks, one on oil exploration work in France, the second on correlation of strata by microfacies. These talks were sponsored by the University of Cairo, the University of Alexandria, the Institut d'Égypte, and the Geological Society of Egypt.

RUSHDI SAID
Cairo University
Cairo, Egypt

MIDDLE EAST

MAX CHATTON

Another year has passed, and the time has come to report on the Middle East. For several of us, 1955 was a home-leave year; as usual, this meant a more strenuous time for those who stayed, for routine work must be dealt with rapidly in the oil industry.

Iraq

Dr. R. C. van Bellen of Kirkuk reports that he took over H. V. Dunnington's work during the latter's absence on leave. Dunnington went on an extensive tour in the United States. At the last A.A.P.G. Annual Meeting, in New York, he spoke on migration, accumulation and dissipation of oil in northern Iraq. Another paper presented by Dunnington at the same meeting, "Close zonation of Upper Cretaceous globigerinal sediments by abundance ratios of *Globotruncana* species groups," was later published (Micropaleontology, vol. 1, no. 3, 1955). Dunnington's tour lasted about two months, after which he went on a well-earned four months' leave in the United Kingdom.

During his absence, Dr. van Bellen dealt with three wildcat wells in the Mosul Petroleum Company's concession and a number of wells in the Iraq Petroleum Company's concession. For three months he also replaced the Divisional Geologist who normally deals with matters in the Mosul Petroleum area. It is hardly surprising, therefore, that an article on the stratigraphy of the Main Limestone of the Kirkuk oil field, which had been planned for the summer of 1955, is now expected to appear some time around the end of the year, in the Journal of the Institute of Petroleum.

Persian Gulf

M. Chatton has been busy during the past year working out the stratigraphy, extending from the Carboniferous to the Miocene, of newly explored parts of Oman. A new wildcat in Trucial Coast has added much to our knowledge of the geology of this part of the world, where all the outcrops show flat-lying Miocene beds unconformable upon earlier Tertiary sediments that pass westward from Lower Oligocene into Middle Eocene. During the summer of 1955, Chatton went on home leave, and had the opportunity of meeting colleagues from Germany, France, Austria, Switzerland, and The Netherlands during a very enjoyable and interesting Paleontological excursion held at Hannover.

Since the Shell Oil Company settled in Doha (Qatar), stratigraphic research based on their Matbakh well has been undertaken by their paleontologist, W. Bisig. We welcome Dr. Bisig among us. He is a former student at the University of Zurich, and we feel sure that he will add much to our knowledge of Persian Gulf stratigraphy.

MAX CHATTON
Qatar Petroleum Company Ltd.
Dukhan, Qatar

PORTUGAL

JAIME MARTINS FERREIRA

Companhia dos Petrolios de Portugal

Micropaleontological activities have lately been almost entirely confined to the study of the upper part of the lower Lusitanian (lower Lusitanian V and top of the lower Lusitanian IV), and of the lower part of the Abadia formation (middle and lower) in the Abadia Valley. In the course of this work, we have found it very difficult to obtain good stratigraphic data in the sections studied, because of the scarcity of fossils and their poor state of preservation. The lower Lusitanian is principally composed of hard limestones, from which the extraction of microfossils is rather difficult. However, the results of our work so far can be summarized as follows:

In the Abadia formation, we have not yet been able to determine any microfossils of good stratigraphic value, but there is a small *Serpula* with a pentagonal cross section in this formation, which we have not yet seen in any other formation. Its stratigraphic value cannot be established, however, until it is found elsewhere.

In the lower Lusitanian we have determined two horizons in the Abadia Valley region, although we do not yet know their lateral extent. One of the horizons is characterized by charophytes, which have demonstrated their stratigraphic value for this restricted area, but their lateral extension is probably small, as they are essentially facies fossils. The second horizon seems to have greater stratigraphic value, as it contains microfossils that are not facies-controlled. It is characterized by certain species of *Discorbis* and *Martinottiella*, associated with *Textularia*, *Verneuilina*, rare *Robulus*, and ostracodes.

JAIME MARTINS FERREIRA
Lisbon, Portugal

UNITED STATES — EASTERN

A. R. LOEBLICH, JR.

American Museum of Natural History, New York

The principal activity of the Department of Micropaleontology remains the production of supplements to the Catalogue of Foraminifera and the publication of the Catalogue of Ostracoda. Seven volumes of the latter work have been issued so far, and subsequent volumes will continue to be published at the rate of two per year. The publication "Micropaleontology" has become a major activity of the Department during the past year, and promises to remain in that category indefinitely.

In spite of these activities, Angelina R. Messina has managed to continue her work on living foraminifera with a field season on Sanibel Island, off the west coast of Florida. Experimental ecological work continues in the laboratories of the Department.

A number of foreign scientists have visited or worked in the Department during the past year. Among these were Professor Eugenia Montanaro-Gallitelli of Modena, Italy; Dr. Heinrich Hiltermann of Hannover, Germany; Yeditore Nagappa of Digboi, Assam; Miss Dora Guttierez of Lima, Peru; Mrs. Clemencia Téllez-Girón of Mexico City; Dr. M. A. Ghorab of Cairo; Dr. Viktor Petters of Bogotá, Colombia; Dr. William Hoffmeister of Tulsa, Oklahoma; and Dr. Richard Bramkamp of Dhahran, Saudi Arabia.

Frank V. Stevenson, who has generously supported the work of the Department over a long period of time, has just donated a Ramsden eyepiece with micrometer to further work in the new spore and pollen program established in association with New York University.

New York University, Department of Geology

The close association between New York University and the American Museum of Natural History in the training of graduate students in micropaleontology continues with increasing effectiveness. The new spore and pollen training and research center, made possible by grants from the Socony Mobil Oil Company and The Texas Company, has broadened the scope of this activity considerably, and will be even more effective when the new laboratory has been completed. Professor L. R. Wilson of the University of Massachusetts is teaching a graduate course in spores and pollen at the center this year, and will also have charge of research on plant microfossils.

Twenty students are enrolled in graduate courses in plant and animal micropaleontology, and eleven others are working on special research problems. Of the latter, Jerome Brock is working on an ecological field study of Recent foraminifera of the west coast of Florida, while Emanuel Nieves and Peter D'Errico are conducting a similar study in Upper New York Bay. Hans Behm is working on the living brackish-water arenaceous foraminifera of Staten Island. David Hughes is engaged in a study of the stratigraphy and micropaleontology of the Cyrenaican coast, North Africa, and Peter Tuozzolo is working on the Tertiary of Maryland

and Delaware. A thin-section study of smaller foraminifera in random orientation is being made by Robert Germeroth, and Jerome Brock is preparing plastic mounts of foraminifera for teaching purposes. Josephine Sperrazza, Humbert Revel, and Peter D'Errico are engaged in compiling a catalogue of index fossils according to authors.

David Hughes and Foster Smith, who is now on leave from the Socony Mobil Oil Company, are assisting Brooks F. Ellis in studying sediments and Recent foraminifera collected by Dr. Ellis in the Persian Gulf last year. A similar study, known as the Long Island Sound Project, is now being made under the joint auspices of the Department of Micropaleontology of the American Museum of Natural History and the Department of Geology of New York University. Jerome Brock, Peter D'Errico, Emanuel Nieves, Robert Popper, David Hughes, and Hans Behm are engaged in this work, and are ably assisted by Jay Bartels of Paterson, New Jersey, and his group of skin divers known as "The Diving Jets."

During the past year, three Master's degrees involving theses on foraminifera were granted by the Graduate School of New York University. Lili Ronai wrote on "Recent reef-living foraminifera of Barbados, B.W.I.," Jules Sachs on "A stratigraphic analysis of the Zeuglodon-bearing bed, Jackson formation, Cocoa Post Office, Alabama," and Ralph Biel on "Foraminifera from the Upper Cretaceous of Delaware." Miss Ronai is now working for the Carter Oil Company in Tulsa, Jules Sachs is with the Gulf Oil Corporation at Houston, and Ralph Biel is working for the International Petroleum Company in Bogotá, Colombia.

Smithsonian Institution (U. S. National Museum), Washington, D. C.

During 1955, the amount of space devoted to the collections has been increased by 25 per cent with the addition of another room and an additional 200 Technicon flat filing cases for storage of slides. Helen Tappan Loeblich, Research Associate, and Alfred R. Loeblich, Jr., are continuing their generic studies for the Treatise on Invertebrate Paleontology. Papers have been completed on several new genera and on a restudy of the genus *Cruciloculina*. In collaboration with Dr. Hans Bolli, Trinidad Leaseholds Ltd., Pointe-a-Pierre, Trinidad, B.W.I., Loeblich and Tappan have also completed a revision of the planktonic foraminifera exclusive of the Heterohelicidae. During the past year, Loeblich made two collecting trips, the first along the Gulf Coast from Florida to Texas and the second in Trinidad.

Professor Eugenia Montanaro-Gallitelli of Modena, Italy, spent several months at the National Museum working on a revision of the Heterohelicidae. Juan Teves of Manila, Philippines, and Miss Dora Gutierrez of Lima, Peru, each spent several months studying foraminifera in the Museum. Others who paid us visits of shorter duration include M. A. Ghorab of Cairo, Egypt; Dr. Hans Bolli and Dr. Hans Kugler of Trinidad; Dr. H. Hiltermann of Hanover, Germany; Dr. Klaus Küpper of Vienna, Austria; M. C. Poddar of Calcutta, India; Dr. K. J. Müller of the Technisches Institut, Berlin, Germany; Dr. Hans Thalmann of Stanford University, Stanford, California; Miss Angelina Messina of the American Museum of Natural History, New York; Edward Stanley of Pennsylvania State University; L. W. LeRoy of the Colorado School of Mines; Samuel Kozak of Brown University; Dr. Harbans Puri of Tallahassee, Florida; Dr. William R. Walton of Houston, Texas; Dr. D. A. Brown of Dunedin, New Zealand; Dr. W. S. Cole of Ithaca, New York; Dr. Wayne Moore of Blacksburg, Virginia; and J. B. Sachs of New York.

U. S. Geological Survey, Washington, D. C.

Dr. Harlan Bergquist is completing work on the stratigraphic paleontology of wells drilled in northern Alaska, including strata ranging in age from Triassic to Upper Cretaceous. Raymond Douglas has completed a study of some Pennsylvanian and Permian fusulinids from Kansas, and is continuing work on a monographic study of American Orbitolinidae. He is also covering this group for the Treatise on Invertebrate Paleontology.

Dr. Will Hass has completed a manuscript on conodonts for the Treatise on Invertebrate Paleontology, and a manuscript on the age and correlation of the Chattanooga shale and the Maury formation, based on conodont studies. He is at present studying conodonts from the Chappel limestone of Texas and the ranges of the conodont genera in the standard Upper Devonian of New York and Mississippian of the central Mississippi Valley area.

Helen Tappan Loeblich is continuing work on the Alaskan Cretaceous foraminifera, and has in press a paper on some new species and genera. Dr. Serge Mamay is studying new fern fructifications containing spores from Illinois and Kansas coal balls.

I. G. Sohn is continuing a revisionary study of late Paleozoic ostracode genera, has compiled a key to Paleozoic species of *Bairdia*, and is working on several families of ostracodes for the Treatise on Invertebrate Paleontology. He has in press a paper on the hydrofluoric acid method of rendering calcareous ostracode carapaces translucent. Ruth Todd is working with Paul Blackmon on the X-ray analysis of foraminiferal tests, and has a preliminary report in press. She is also studying several cores from the western Mediterranean. Two papers written in collaboration with the late Dr. J. A. Cushman and with Mrs. Rita Post, on foraminifera from the Bikini drill holes and the Marshall Islands, appeared during the past year.

U. S. Geological Survey, Jackson, Mississippi

Mrs. Esther Applin is studying arenaceous foraminifera, mainly Saccamminidae, from the Eoline core holes of Mississippi. In addition, she has in preparation a paper on a microfauna of foraminifera and problematica from deposits of Sligo (early Cretaceous) age in southern peninsular Florida.

U. S. Geological Survey, Raleigh, North Carolina

H. E. LeGrand has published a paper on "Brackish water and its structural implication in the Great Carolina Ridge," and worked with P. M. Brown on a guidebook for the coastal plain of North Carolina. P. M. Brown has completed studies of Upper Cretaceous ostracodes from North and South Carolina, some studies of North Carolina wells, including plates on ostracodes, and the stratigraphic revision of the Trent marl of North Carolina.

University of Rochester, Rochester, New York

Lewis E. Stover and K. Norman Sachs are studying the geographic and stratigraphic distribution of ostracodes in the Middle Devonian Moscow formation of New York. Dr. W. R. Evitt is studying silicified Middle Ordovician trilobites and their protaspids, in collaboration with Dr. H. B. Whittington of Harvard University.

Paleontological Research Institution, Ithaca, New York

The Institution has recently published a monograph on the genus *Globotruncana* in northeastern Colombia, by Dr. R. Gandolfi, and another on Upper Devonian Cerro Gordo ostracodes from Iowa, by Lee Gibson.

Cornell University, Ithaca, New York

Philip Hewitt is studying the larger foraminifera from the Eocene and Oligocene of Cuba in the Dorothy Palmer Collection at the Paleontological Research Institution.

Columbia University, Department of Geology, New York

Louis S. Korniker is studying the ecology of living foraminifera and ostracodes from the Bahamas.

Columbia University, Lamont Geological Observatory, Palisades, New York

Robert J. Menzies and staff, Biological Program, are engaged in a study of vertical and horizontal distribution of planktonic foraminifera involving especially a detailed study of *Globorotalia truncatulinoides*. David Ericson, G. Wollin and J. Wollin are working on deep-sea cores of the North Atlantic and South Atlantic Oceans, Mediterranean Sea, and Gulf of Mexico, involving a detailed study of sediments and foraminifera from these cores. K. K. Wang is working on Pleistocene climatic changes as indicated by foraminifera. This project involves a study of numerous deep-sea cores. William Wiles is working on a study of pores in *Globigerinoides* and other planktonic foraminifera. Allan Be is working on Recent planktonic foraminifera recovered from plankton tows.

Yale University, Conservation Program, New Haven, Connecticut

Dr. Paul B. Sears and Dr. Edward S. Deevey, Jr., are working on pollen profiles from the north-central states, the Southwest, Mexico, Central America, and southern Europe.

Harvard University, Cambridge, Massachusetts

R. Cifelli is working on Bathonian foraminifera from Great Britain. He spent last summer collecting in England from the Dorset coast to Lincolnshire.

Brown University, Providence, Rhode Island

Samuel Kozak is working on Upper Cretaceous foraminifera from New Jersey and Delaware.

Pennsylvania State University, University Park, Pennsylvania

Dr. Frank M. Swartz and Dr. Frank C. Whitmore, Jr., have completed a study of late Silurian ostracodes of New Jersey and New York. Dr. Swartz and Charles R. Pickett are working on Middle Ordovician ostracodes from central Pennsylvania. In addition, Dr. Swartz is also working on a revision of late Silurian ostracodes of Virginia and West Virginia. Edward Stanley is studying conodonts.

Rutgers University, New Brunswick, New Jersey

Dr. Stephen Fox is working on foraminifera from the Pierre formation (late Cretaceous) of the western interior. Mrs. Natalie Voshinin has completed a study of foraminifera from the Manasquan marl of New Jersey. Ernest Brownson is studying foraminifera from the New Jersey coastal plain. Harold Gill is working on the micropaleontology of the late Cretaceous of New Jersey. Richard Page is studying the Cretaceous Navesink foraminifera of New Jersey. John McCallom is studying Raritan and Magothy foraminifera.

Princeton University, Princeton, New Jersey

Richard K. Olsson is studying the Cretaceous-Tertiary boundary in New Jersey and the paleoecology of the included foraminifera.

Ohio State University, Columbus, Ohio

Dr. Walter C. Sweet has recently published a paper on the conodonts of the Middle Ordovician Harding formation of Colorado (Jour. Pal., vol. 29, pp. 226-262, 1955), and, with Dr. Grace A. Stewart, has completed a study of Middle Devonian conodonts of Ohio. He is at present working on Cincinnatian conodonts and scolecodonts and on the morphology of the fibrous (neurodontiform) conodonts.

Dr. Charles H. Summerson is working on arenaceous foraminifera, Chitinozoa and scolecodonts from the Middle Devonian Columbus limestone of Ohio. Dr. Mildred F. Marple is studying Pennsylvanian microfossils from eastern Ohio, and recently published a paper on smaller foraminifera from the Pottsville formation of Ohio.

West Virginia Geological Survey and University, Morgantown, West Virginia

Aureal T. Cross and Mart P. Schemel are engaged in a long-term study of plant microfossils of the Appalachian area as a portion of the West Virginia Geological Survey's coal research program. To date, major emphasis has been placed on the Upper Pennsylvanian and Permian coals of the Ohio Valley drainage area, including Allegheny, Conemaugh, Monongahela, and Dunkard strata. A particularly important phase of the recent work has been to develop methods and corroborative data on plant-microfossil assemblages, in order to identify coal

seams by means of the microfossils separable from coal chips in cuttings obtained in oil and gas drilling. Some positive results of this work are incorporated in the research projects described below.

Two projects nearing completion are studies involving Allegheny—Conemaugh correlations in the Northern Panhandle counties and areas adjacent to the Burning Springs anticline, and the classic Pittsburgh-Pomeroy problem of the southern Ohio Valley area in West Virginia and Ohio. Studies have been made of all coals in these sequences.

Dr. Cross, in a project financed in part by funds of the Geological Society of America, is studying European Carboniferous plant microfossils from both coal macerations and fructifications. Mr. Schemel is investigating the Allegheny plant microfossils of the eastern and southern outcrop belt in West Virginia, in an attempt to correlate the coals more precisely with the type areas in Pennsylvania. George Denton, a graduate student at the University, is engaged in a cooperative study with the Ohio Geological Survey involving tracing the lower Allegheny coals from Pennsylvania type-areas across the Northern Panhandle and into Ohio by means of plant microfossils and other data.

An interesting portion of the subsurface studies of Russell Flowers, of the West Virginia Geological Survey, is the recognition and establishment of a zone of foraminifera in the Greenbrier limestone (Middle Mississippian) over much of the area of its distribution in West Virginia. Some of these results have been presented in a thesis to the Department of Geology of West Virginia University and are being prepared for publication. Along with other aspects of coal geology and paleobotany, Dr. Cross offers course work in identification of plant microfossils and their application in stratigraphic studies.

Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. Wayne E. Moore has completed a study of the geology of Jackson County, Florida, and another on the ecology of Recent foraminifera in the northern Florida Keys. Work is continuing on living foraminifera from Crane Key, Florida, and on some larger foraminifera from the Eocene of Europe.

Duke University, Durham, North Carolina

Dr. E. Willard Berry has completed the description of two new species of *Cyclammina*, and is working on coal spores from Africa.

University of Mississippi and Mississippi Geological Survey, University, Mississippi

Dr. Robert H. Shaver is completing studies of the ostracode families Healdiidae and Bairdiidae for the Treatise on Invertebrate Paleontology. R. J. Hughes is completing a study of foraminifera from Kemper County, Mississippi.

University of Alabama, University, Alabama

James Harris is studying the microfauna of the Providence sand.

McLean Foraminiferal Laboratory, Alexandria, Virginia

James D. McLean, Jr., has nearly completed the study of the Yorktown Miocene foraminifera, a National Science Foundation research project sponsored by the Paleontological Research Institution. The project has been extended to include the ostracodes as well.

The Laboratory is publishing a study of Vincentown foraminifera by Dr. Jan Hofker and a contribution by Mr. McLean on two new guide foraminifera from Maryland. In addition, work is continuing on the McLean Card Catalog of foraminifera, the fortieth unit having been completed.

University of Tennessee, Knoxville, Tennessee

R. E. McLaughlin is currently working on spores and pollen from the Eocene and Paleocene of Tennessee, and on palynological studies of Tertiary lignites from near Chattanooga, Tennessee, and from other areas.

ALFRED R. LOEBLICH, JR.
U. S. National Museum
Washington, D. C.

UNITED STATES—MID-CONTINENT

DOROTHY JUNG ECHOLS

University of Missouri, Columbia, Missouri

Dr. Raymond E. Peck reports the following news items: Mrs. Jessie Bird Ellis is working on an abundant, varied, and distinctive Devonian conodont fauna from the patchily distributed shale-sandstone-conglomerate "detrital beds" between the Cotter dolomite (Lower Ordovician) and the Callaway limestone (Middle Devonian) of west-central Missouri. Walter Niewoehner is studying a large collection of ostracodes from the Louisiana limestone (Devonian?) of northeastern Missouri. M. G. Mehl is in the second year of his study of the basal relations of the Mississippian of Missouri and of limited areas in Arkansas, Iowa, and Illinois. The study is based primarily on conodont evidence. Wm. Daughdrill is working on the foraminifera of the Archusa of the Wautubbee marl (Claiborne Eocene) for his M.A. thesis. R. E. Peck has in press a manuscript on the North American Mesozoic Charophyta. He is presently working on the Charophyta for the Treatise on Invertebrate Paleontology.

Saint Louis University, St. Louis, Missouri

Dr. Kenneth G. Brill informs us that there are no projects in micropaleontology at St. Louis University this semester.

University of Oklahoma, Norman, Oklahoma

Irwin B. Gold has begun work on a Ph.D. thesis on the Lower Miocene of the Santa Barbara, California, area. He will attempt to work out the Paleoecology and geologic history by a

combined detailed faunal and sedimentary analysis of auger samples supplied by the Standard Oil Company of California. Gold holds a Humble Oil & Refining Company fellowship. The work is being done under the direction of Dr. Doris Malkin Curtis.

Dr. R. W. Harris reports that the following two papers will soon appear: "Notes concerning a Senonian valvulinerian," by R. W. Harris and C. L. McNulty, is being submitted for publication in the Journal of Paleontology; "Foraminifera and Ostracoda from the Ringwood Pool of Oklahoma," by R. W. Harris and T. C. Jobe, is now ready for publication by the Oklahoma Geological Survey.

University of Tulsa, Tulsa, Oklahoma

Dr. Edward Heuer reports: We have several students doing course work in micropaleontology this year, but we do not have any graduate students doing research. In my own work, I have become rather deeply engrossed in the application of statistical analysis to taxonomic and paleoecologic studies of Pennsylvanian microfossils from the Mid-Continent area. At present, I am primarily engaged in seeking out appropriate statistical methods, and in studying the results obtained by applying different statistical methods to the same samples. Although the work is proving quite difficult from the standpoint of understanding statistical procedures and properly interpreting the results in terms of taxonomy and paleoecology, I feel rather strongly that the statistical analysis of populations is fundamental to virtually all phases of micropaleontologic research.

Missouri School of Mines, Rolla, Missouri

Dr. Don L. Frizzell submits the following news items: We have no graduate students in micropaleontology at present, although three students are taking the elementary course. Last spring semester, B. G. Deaver received the Master of Science degree with an excellent thesis on "Morphology and systematic position of some anomalinid foraminifera." His project was facilitated by the use of a biological research microscope lately purchased by our department. With this addition to our equipment, we are in a position to offer some elementary work on spores and pollen, as well as some of the other smaller microfossils.

My wife and I (D. L. Frizzell and Harriet Exline) have in press our "Monograph of fossil holothurian sclerites," to be published in the Missouri School of Mines Bulletin, Technical Series. In addition, our more general paper entiled "Micropaleontology of holothurian sclerites," presented at the New York S.E.P.M. symposium, has been published in Micropaleontology (vol. 1, no. 4, 1955). Another paper, "Revision of the family Synaptitidae, fossil holothurian sclerites," was presented in November, 1955, before the First Peruvian Geological Congress.

Washington University, St. Louis, Missouri

In the micropaleontologic laboratory at Washington University, work continues as usual. This summer your correspondent took an extensive trip throughout the West and was able to collect a number of interesting samples for our collection. In November, along with most of the staff, we attended the G.S.A. annual meeting at New Orleans.

This fall semester we have been pleased to welcome several visitors to our department. The following former graduate students paid us visits: Jack Gouty, now a micropaleontologist with Shell in New Orleans, spent several days with us and very kindly donated a fine collection of Tertiary type material from the Gulf Coast. Tom Pappas spent a few days reviewing his photographic techniques for some of our present students. Warren Baumgartner, until recently with The Texas Company, stopped by on his way to Oregon as an ensign in the Coast Guard; he will be in service three years and will then return to The Texas Company. Paul Beach, now with the Standard of Texas in Houston, and Bernie Hill, of the California Company in New Orleans, also spent some time with us during their vacations.

After three years in Australia, Mrs. Betty Kellett Nadeau has now returned to the United States. Your correspondent was delighted to have her spend nearly a week here in St. Louis. For the next several months Mrs. Nadeau may be reached in care of Mr. Edward Nadeau, Socony Mobil Oil Refinery, Elk Street, Buffalo, New York. Dr. H. Hiltermann, from Hannover, Germany, spent a few days with us in November. He was en route from California to New York; he returns to Germany early in December. Dr. Doris Malkin Curtis, who now teaches at the University of Oklahoma, spent a day with us in the latter part of November.

Harold Levin, a graduate teaching assistant last year, has been awarded a University Fellowship in Geology. He is a Ph.D. candidate for June, 1956, and is hard at work on his thesis, which deals with Wilcox Eocene micropaleontology with particular emphasis on the development and stratigraphic significance of the Amphisteginidae. The thesis will include a reconstruction of the environment of deposition as revealed in a quantitative and qualitative analysis of the subsurface microfauna and lithology of the Wilcox Eocene of Florida. The investigation will be closely coordinated with a biostratigraphic study designed to establish definite correlative zones. Dr. William Johns, who has joined our geologic staff, has agreed to help Levin X-ray some of his forams in order to clarify their internal structure. This will be done in addition to thin-sectioning.

Wayne Hill, a new Master's candidate, who holds the Atlantic Refining Company scholarship and received his B.S. from the University of Illinois, shows considerable promise of becoming a fine micropaleontologist. His thesis problem has not been chosen as yet. Bill Creath has gone to work for Dr. A. F. Frederickson with the Stanolind Oil and Gas Company, doing geologic research at Tulsa, Okla-

homa. He has been organizing a micropaleontologic library and collecting samples for study.

Dean Henry Andrews of the School of Botany, Washington University, reports that there are two graduate students in paleobotany studying for advanced degrees. Father Gustava Huertas, a priest from Bogotá, Colombia, is here on a Guggenheim Fellowship to learn paleobotanical techniques. He has been working on some significant leaf remains (cordates and ferns) occurring in coal balls. He is developing a technique for getting these remains out intact instead of working on peels, and he has been quite successful in the process. This research project is being carried on in connection with his Master's thesis.

Miss Janet Winstead, who has an M.A. from Ohio University, is studying for her Ph.D. under Dean Andrews' direction. She has been working on Carboniferous ferns, but her thesis problem has not yet been chosen. Dr. Andrews has in press a paleobotanical review, "Phytomorphology," prepared for an Indian journal. In April, 1955, his "Index of generic names of fossil plants, 1820-1950," based on the Compendium Index of Paleobotany of the United States Geological Survey, was published as United States Geological Survey Bulletin no. 1013.

DOROTHY JUNG ECHOLS
Washington University
St. Louis, Missouri

UNITED STATES—NORTH-CENTRAL

R. M. STAINFORTH

This news report, the first from north-central United States, is short in relation to the size of the territory covered, mainly because your correspondent is a newcomer to the region and did not find time to circularize potential contributors until late in July, when most universities were closed for the summer vacation. The north-central area is arbitrarily defined as Montana and Wyoming, Minnesota and the Dakotas, Wisconsin, Illinois, Michigan, and Indiana. News items from micropaleontologists active in the area will be welcomed for inclusion in future reports.

University of Chicago

J. M. Weller has discussed the pros and cons of formally recognizing the "Protista" as an organic kingdom separate from both plants and animals (Jour. Pal., vol. 29, pp. 707-710, 1955). He concludes that such a procedure is undesirable, and would raise more problems than it solves.

Chicago Natural History Museum

S. K. Roy reports as follows: "This Museum touches upon microfossils only occasionally and incidentally, but it happens that we have some in hand just at this time. Dr. Rainer Zangerl, Curator of Fossil Reptiles, and Dr. Eugene S. Richardson, Jr., Curator of Fossil Invertebrates, have been occupied for about a year in splitting a good-sized sample (about 200 cubic feet) of Middle Pennsylvanian black shale from Mecca, Indiana. The object of this study is to determine the ecologic changes accompanying a marine transgression, with the aid of charts drawn to show the position and orientation of every scrap of fossil for each quarter-inch of shale as an arbitrary time-unit. They are constructing abundant diagrams for the various species represented, with some interesting fluctuations coming to light. Along with the larger fossils (sharks and shark allies, paleoniscoid fishes, and crustaceans), they find that conodonts are relatively abundant in certain levels but rare in others. A few groups of associated form-genera have turned up. These, together with the run-of-the-mill individual specimens, have been turned over to Frank H. T. Rhodes at the University of Illinois, along with a smaller sample of the shale for him to split into layers smaller than the quarter-inch unit. The megafossils are rather evenly distributed within the thickness of a quarter-inch level, but the pattern of abundance of the conodonts seems to vary notably from millimeter to millimeter. Thus these microfossils may reveal a different picture of the changing conditions than will the megafossils — a picture probably more sharply in focus though less inclusive. There are no other microfossils in the fauna. Search for ostracodes and foraminifera has so far been futile."

University of Michigan

R. V. Kesling has published some results of his studies of Devonian ostracods: "Oncotechmoninae, a new subfamily of entomoconchid ostracods from the Middle Devonian of New York" (Jour. Pal., vol. 28, pp. 575-580, 1954), and, with T. E. Kilgore, "*Bairdia epicypha*, new name for *Bairdia gibbera* K. & K., 1952, non Morey, 1935" (ibid., vol. 29, p. 189, 1955). The species referred to in the latter note is from the Devonian Genshaw formation of Michigan.

Michigan State College

W. A. Kelly reports completion of a paper on Mississippian ostracodes, now in press for the Journal of Paleontology. This represents part of a continuing program of microfaunal analysis of field and subsurface samples. Mrs. Jane Smith is working on Devonian microfaunas.

University of Minnesota

F. M. Swain recently published an important ecologic paper entitled "Ostracoda of San Antonio Bay, Texas" (Jour. Pal., vol. 29, pp. 551-646, 1955). He shows that the distribution of living ostracods in the area is governed by three major biofacies and three subfacies. A wealth of ecologic detail is included, along with a careful systematic discussion.

Montana State University

F. S. Honkala reports that there is no activity in our field at present. The only paleontologist on their staff is a vertebrate specialist, R. M. Fields.

University of North Dakota

Bulletin 28 (1955) of the North Dakota Geological Survey consists of contributions to the geology of the state by the students and staff of the University. One of these, by A. C. Grunseth, describes a foraminiferal fauna from the Niobrara formation of northeastern North Dakota, comparable to the material described from Nebraska by Loetterle.

University of Notre Dame

R. C. Gutschick has reported on some siliceous microfossils found in acid-insoluble residues of the Mifflin limestone (Middle Ordovician) of Illinois. They include a new sponge, *Astraeospongia dixonensis*, based on octactinellid spicules, and a new holothurian genus, *Thuroholia*, based on distinctive sieve plates (Jour. Pal., vol. 28, pp. 420-433, 827-829, 1954).

University of Wisconsin

Before departing for Brazil, E. J. Zeller found time to send in a brief report. He and his wife, Doris E. Zeller, are leaving to set up a paleontological laboratory for Petrobras in Belem, and expect to be away for three years. J. L. Wray is currently studying the Mississippian microfossils of the central Appalachian area, including Virginia, West Virginia, Ohio and Pennsylvania, as a basis for his Ph.D. thesis. In a discussion of age-significant fossils of the Mississippian and Pennsylvanian of western Montana, L. R. Laudon refers to certain conodonts and fusulinids (Billings Geol. Soc., 6th Ann. Field Conf., Guidebook, pp. 208-210, 1955).

University of Wyoming

A new siliceous sponge, *Gallatinospongia*, from the Cambrian of Wyoming, is described jointly by V. J. Okulitch of the University of British Columbia and W. G. Bell of the University of Wyoming (Jour. Pal., vol. 29, pp. 460-461, 1955). The genus is defined in part by its spicular texture as revealed by microscopic examination of thin sections.

Carter Oil Company

In the Billings, Montana, office, a new section is devoted to regional stratigraphic studies. R. M. Stainforth is in charge of this work, and is assisted by L. G. Pope and L. Weiss, who until recently was our correspondent in Peru. Micropaleontological techniques will be applied wherever appropriate. Just before going to Billings, Stainforth spent three months on a special assignment with Esso Standard S.A.F. in the Bordeaux area, where he had the pleasure of meeting his French colleagues F. Dalbiez and A. Debourle. (In passing, it may be noted that the sequence of planktonic foraminifera in the Aquitaine Basin proved to be almost identical with the succession known in the Caribbean region. This fact is already well known to French paleontologists, but has received scant notice in the literature.)

Some recent papers published by Carter Oil Company personnel refer to the north-central states. They include "Mississippian plant spores from the Hardinsburg formation of Illinois and Kentucky" (Jour. Pal., vol. 29, pp. 372-399, 1955) and "Geologic range of Paleozoic plant spores in North America" (Micropaleontology, vol. 1, pp. 9-27, 1955), both by W. S. Hoffmeister, F. L. Staplin, and R. E. Malloy of the Tulsa research laboratory. Another paper is by T. B. Coley, of Jackson, Mississippi: "Stratigraphic distribution and correlation of some Middle Devonian Ostracoda" (Jour. Pal., vol. 28, pp. 452-464, 1954). This paper refers in particular to the Silica shale near Sylvania, Ohio, and suggests a Ludlowville age rather than the usually accepted Skaneateles — Marcellus correlation for this formation.

R. M. STAINFORTH
Carter Oil Company
Billings, Montana